# Basics in Minerals Processing

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# Metso Mining and Construction

## Brand names in rock and minerals processing

Allis Chalmers (AC)
Allis Minerals System
Altairac
Armstrong Holland
Barmac
Bergeaud
Boliden Allis
Cable Belt
Conrad Scholtz
Denver
Dominion
FACO
GFA
Hardinge
Hewitt Robins
Kennedy Van Saun KVS
Kue-ken Seco
Koppers
Lennings
Lokomo
Marcy
Masterscreens
McDowell Wellman
McNally Wellman
Neims
NICO
Nokia
Nolan
Nordberg
MPSI
Orion
PECO
Pyrotherm
Read
REDLER
Sala
Scamp
Skega
Stansteel
Stephens – Adamson
Strachan & Henshaw
Svedala
Thomas
Tidco
Trellex
Tyler

Notes

Notes

*"The practice of minerals processing is as old as human civilization. Minerals and products derived from minerals have formed our development cultures from the flints of the Stone Age man to the uranium ores of Atomic Age".*

The ambition with this handbook, "Basics in Minerals Processing", is not to give a full coverage of the subject above.

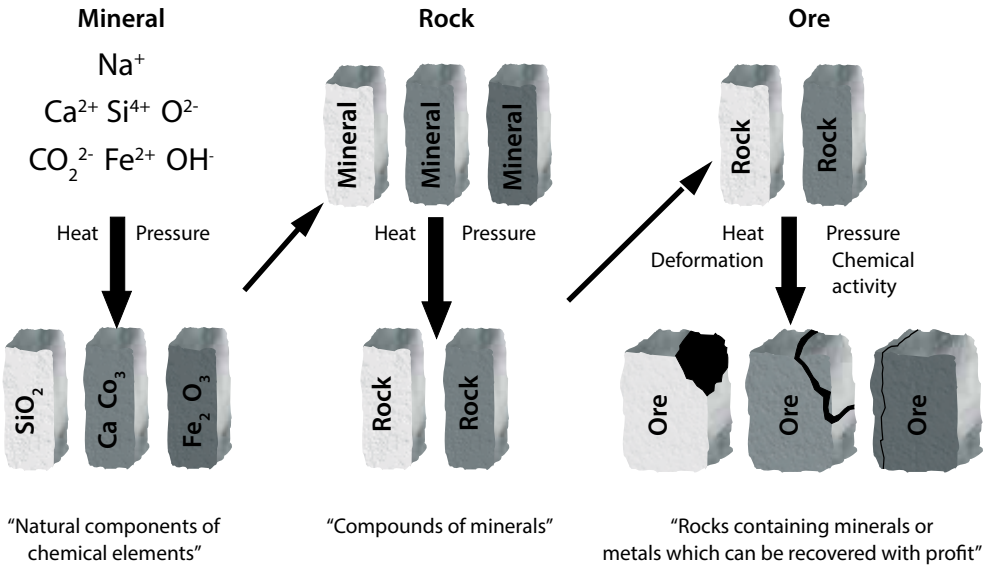
The intention is to give technicians involved in mineral operations practical and useful information about the process equipment used, their systems and operational environment.

The technical data given are basic, but will increase the understanding of the individual machines, their functions and performances.

Always contact Metso for information regarding specific products since the data given is subject to change without notice.

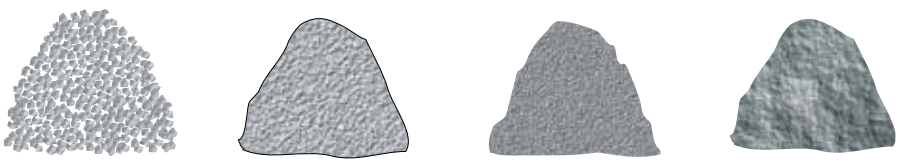
## *Basic definitions*

It is important to know the definitions of *mineral, rock* and *ore* as they represent different product values and partly different process systems



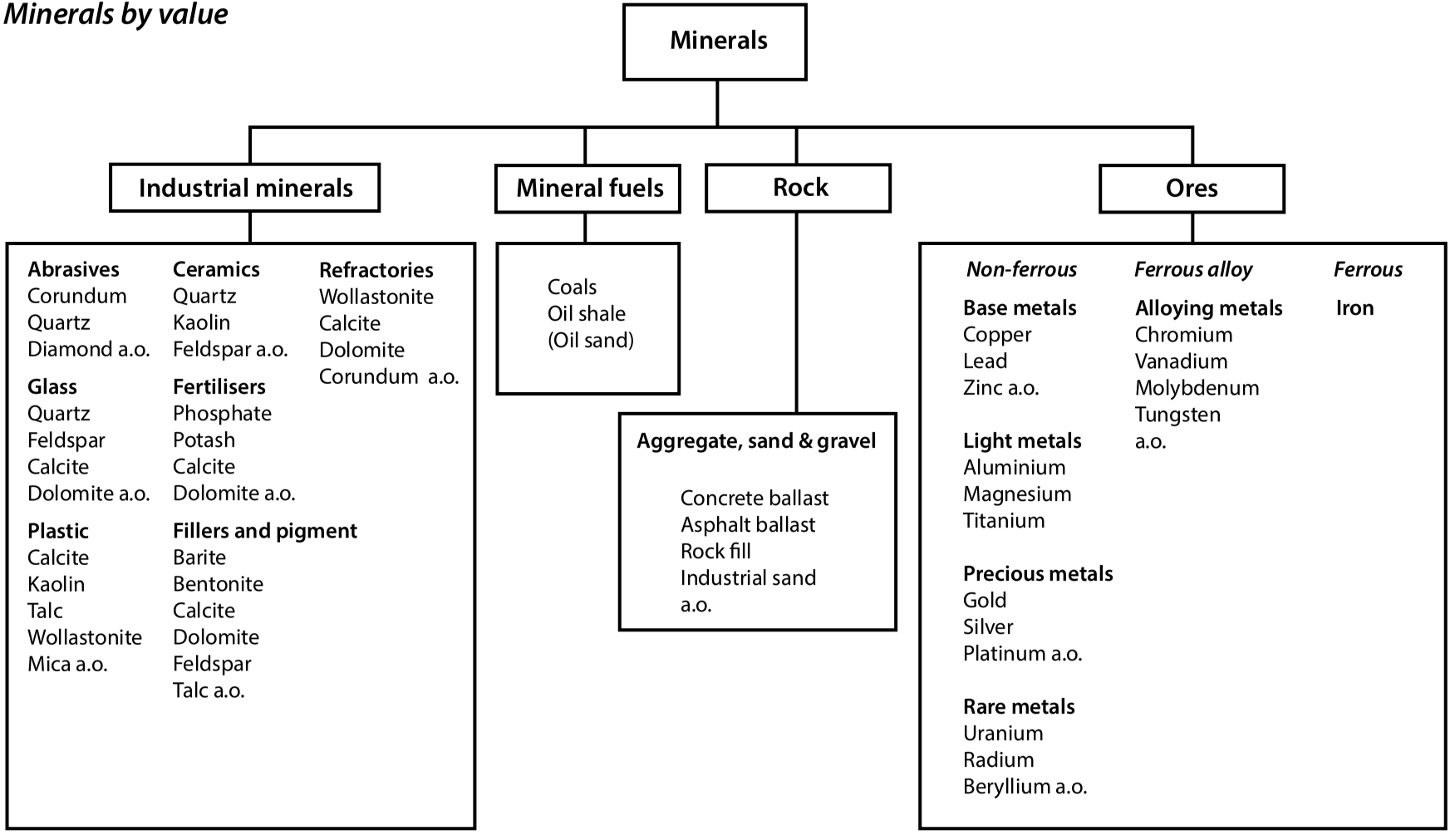

**Artificial minerals**

"Man made" minerals are not minerals by definitions. But from processing point of view they are similar to virgin minerals and are treated accordingly (mainly in recycling processes).



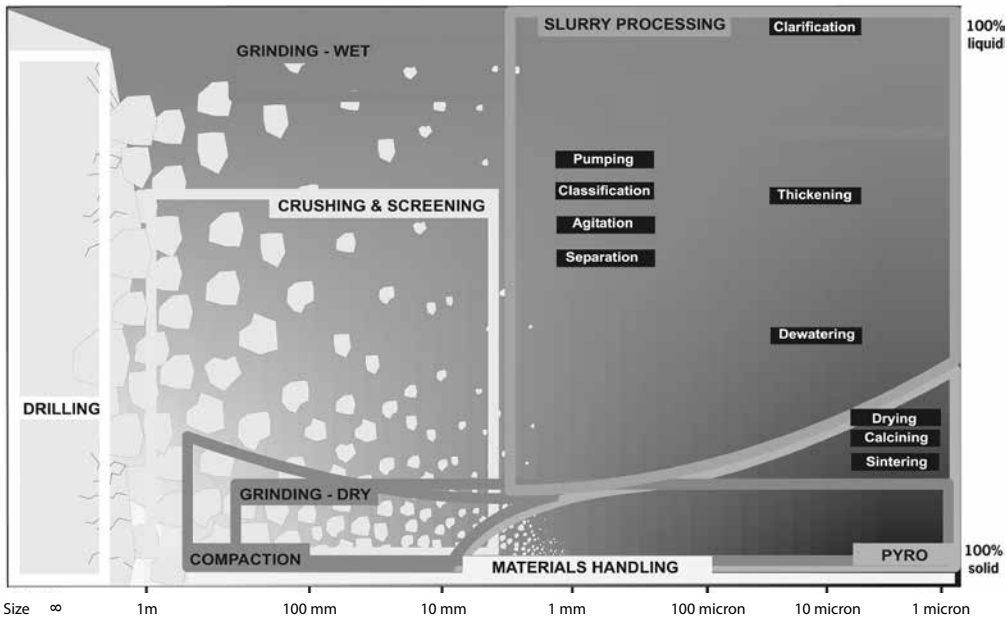
Slag | Concrete | Mill scale | Glass & Ceramics

## *Minerals by value*



## *The process frame of minerals*

The goal in mineral processing is to produce maximum value from a given raw material. This goal can be a crushed product with certain size and shape or maximum recovery of metals out of a complex ore.
The technologies to achieve these goals are classical, complementary and well defined.
Below they are presented in the Process Frame of Minerals, classified according to their interrelations in product size and process environment (dry or wet).




**Drilling** (and blasting) is the technology of achieving primary fragmentation of "in situ" minerals. This is the starting point for most mineral processes with the exception of natural minerals in the form of sand and gravel.

**Crushing and screening** is the first controlled size reduction stage in the process. This is the main process in aggregate production and a preparation process for further size reduction.

**Grinding** is the stage of size reduction (wet or dry) where the liberation size for individual minerals can be reached. By further size reduction filler (mineral powder) is produced.

**Slurry processing** includes the technologies for wet processing of mineral fractions.

**Pyro processing** includes the technologies for upgrading of the mineral fractions by drying, calcining or sintering.

**Materials handling** includes the technologies for moving the process flow (dry) forward by loading, transportation, storage and feeding.

**Compaction** of minerals includes the technologies for moving and densifying minerals by vibration, impaction and pressure, mainly used in construction applications.

## *Mineral processing and hardness*

All deposits of minerals, rock or ores have different hardness depending on the chemical composition and the geological environment.

**Mohs numbers are a simple classification:**

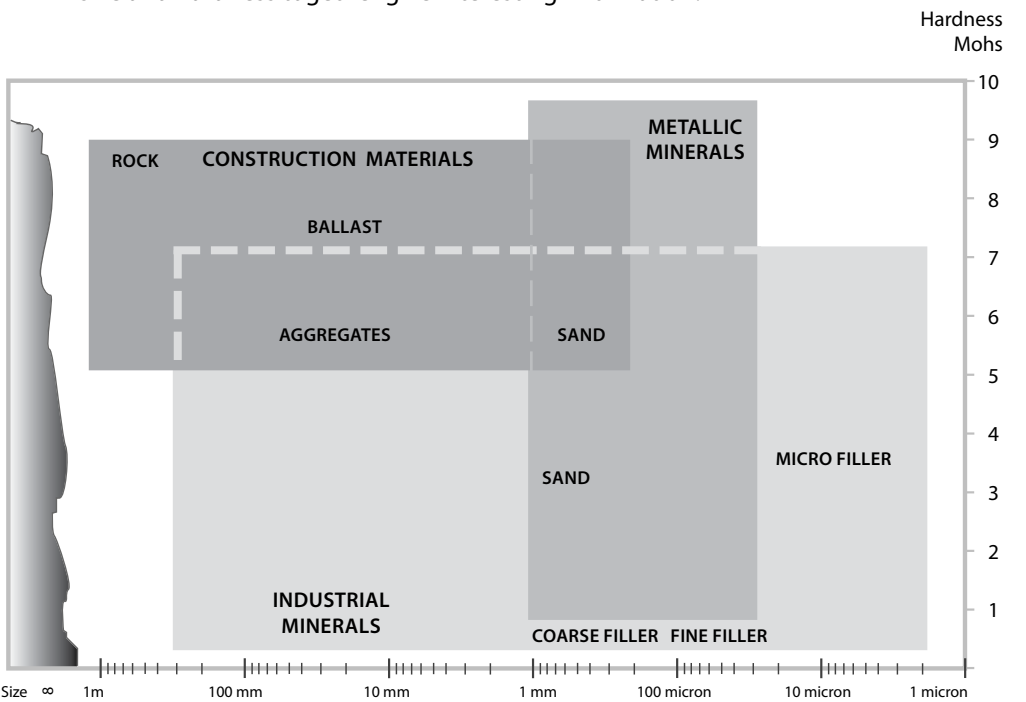
| | | | |
|---|---|---|---|
| 1. | Talc | Crushed by a finger nail | Graphite, Sulphur, Mica, Gold |
| 2. | Gypsum | Scratched by a finger nail | Dolomite |
| 3. | Calcite | Scratched by an iron nail | Magnesite |
| 4. | Fluorite | Easily scratched by a knife | Magnetite |
| 5. | Apatite | Scratched by a knife | Granite, Pyrite |
| 6. | Feldspar | Hardly scratched by a knife | Basalt |
| 7. | Quartz | Scratches glass | Beryl |
| 8. | Topaz | Scratched by quartz | |
| 9. | Corundum | Scratched by a diamond | |
| 10. | Diamond | Cannot be scratched | |

*In 1813 an Austrian geologist, Mr. Mohs, classified minerals according to their individual hardness.*

In operation we naturally need more information about our feed material.
See information on **work index** and **abrasion index**, section 3 page 2.

## *Size and hardness*

All operations have different process environments due to mineral hardness and size range. It is important to know in which "range" we are operating as this will affect many process parameters, (wear rate, uptime, operation costs etc.).
Size and hardness together give interesting information.

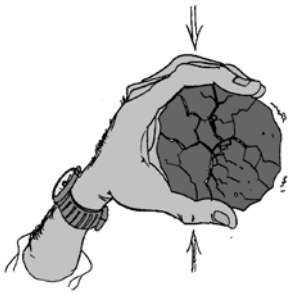


## *The stress forces of rock mechanics*

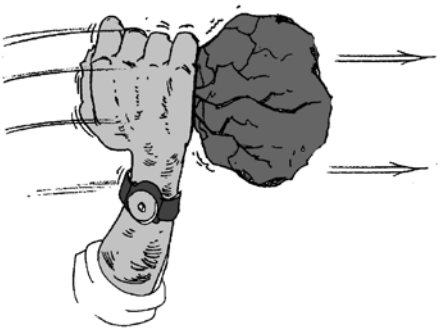
Beside size and hardness, the classical stress forces of rock mechanics are the fundamentals in most of what we do in mineral processing. They guide us in equipment design, in systems layout, in wear protection etc. They are always around and they always have to be considered.

**Tensile**

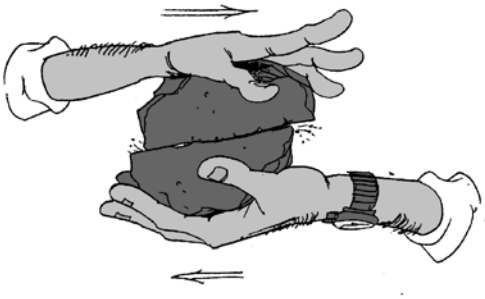
**Compression**



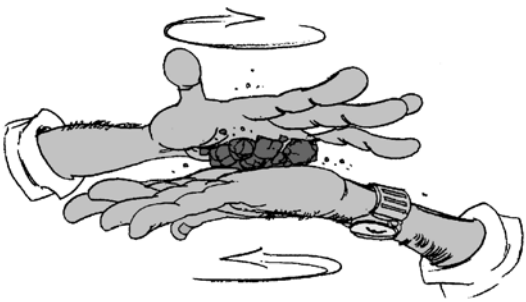
**Impaction**



**Shearing**



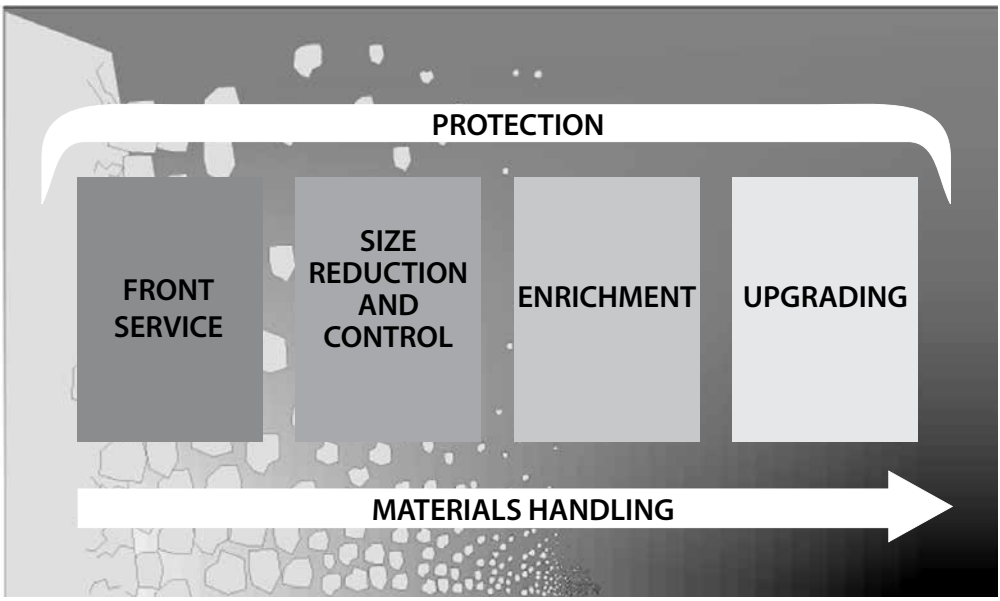
**Attrition**



## *Operation stages*

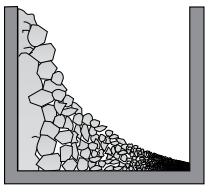
The operating stages in minerals processing have remained the same for thousands of years. Of course we have come far in development of equipment and processes since then, but the hard, abrasive and inhomogeneous mineral crystals have to be treated in special ways in order to extract maximum value out of each size fraction.

The operation pattern below has been used since the days of "mineralis antiqua"



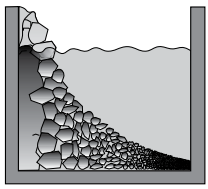

| | |
|---|---|
| **Front service:** | Starting point of mineral processing |
| **Size reduction & control:** | Processes to produce requested size distributions from feed material |
| **Enrichment:** | Processes to improve value of minerals by washing and/or separation |
| **Upgrading:** | Processes to produce requested end products from value and waste minerals. |
| **Materials handling:** | Operations for moving the processes forward with a minimum of flow disturbances |
| **Protection:** | Measures to protect the process environment above from wear and emissions of dust and sound |

## *Operation – Dry or wet ?*



**Dry processing**

- When no water is needed for processing
- When no water is allowed for processing



**Wet processing**

In all other cases due to:

- Better efficiency
- More compact installation
- No dusting

**Note! Wear rate is generally higher in wet processing!**

## Mining and quarry fronts

The mining and quarry fronts are the starting points for recovery of rock and mineral values from surface and underground deposits.

Operations are drilling (blasting), primary crushing (optional) and materials handling, dry and wet.

***Mining and quarrying***

***Open pit***

***Underground***

## Natural fronts

In the glacial, alluvial and marine fronts nature has done most of the primary size reduction work.

Raw material such as gravel, sand and clay are important for processing of construction ballast, metals and industrial mineral fillers.

Operations are materials handling (wet and dry) and front crushing (optional).

### Glacial

Glacial sand and gravel occur in areas which are – or have been – covered by ice. The material is rounded and completely unsorted with an heterogeneous size distribution which ranges from boulders larger than 1 m (3 ft) down to silt (2-20 microns). Clay contamination is concentrated in well defined layers.

### *Alluvial*

The size of alluvial sand and gravel depends on the flow velocity of the water, among other things. Normally the maximum size is around 100 mm (4”). Alluvial sand and gravel have a homogeneous size distribution and larger particles often have high silica content. The clay content is often high, normally in the range of 5 to 15 %. Alluvial fronts are in certain areas hosting gold, tin and precious stones.

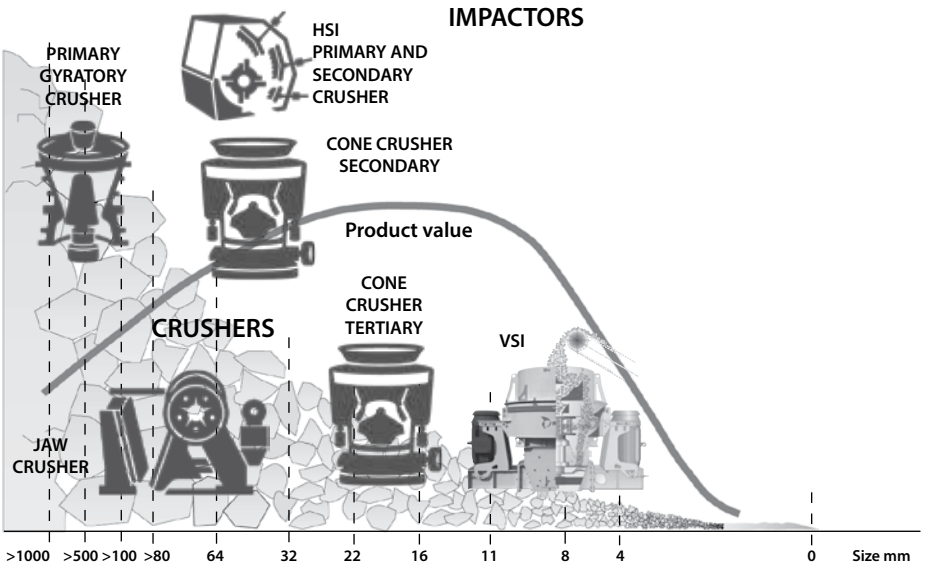
### *Marine*

Marine sand and gravel often have a more limited size distribution than other types of sand and gravel. The minerals in marine sand and gravel have survived thousands – or even millions of years – of natural attrition, from erosion in the mountain ranges and grinding during transport down to the sea. The particles have become well rounded and the clay content is extremely low. Marine fronts are in certain areas hosting heavy minerals like hematite, magnetite, rutile a.o.

# *Size reduction*

## *Crushing of rock and minerals*

By tonnage this is by far the largest process operation in minerals processing. The goal is to produce rock or (more seldom) mineral fractions to be used as rock fill or ballast material for concrete and asphalt production. Quality parameters are normally strength, size and shape. The size fractions, see below, are priced according to defined size intervals and can be reached by crushing only, see section 3.

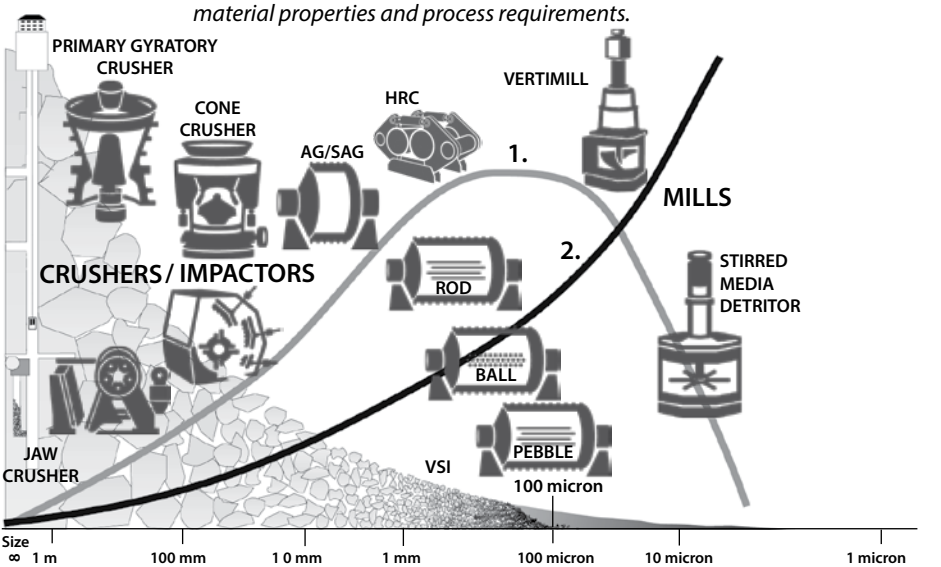



## *Crushing and grinding of ore and minerals*

Size reduction of ores is normally done in order to liberate the value minerals from the host rock. This means that we must reach the liberation size, normally in the interval 100 – 10 micron, see value curve 1 above.
If the raw material is a single mineral (Calcite, Feldspar a.o.) the value normally lays in the production of very fine powder (filler), see value curve 2 below.

In order to maximise the value in size reduction of rock and minerals, see below, we need both crushing and grinding in various combinations, see section 3.

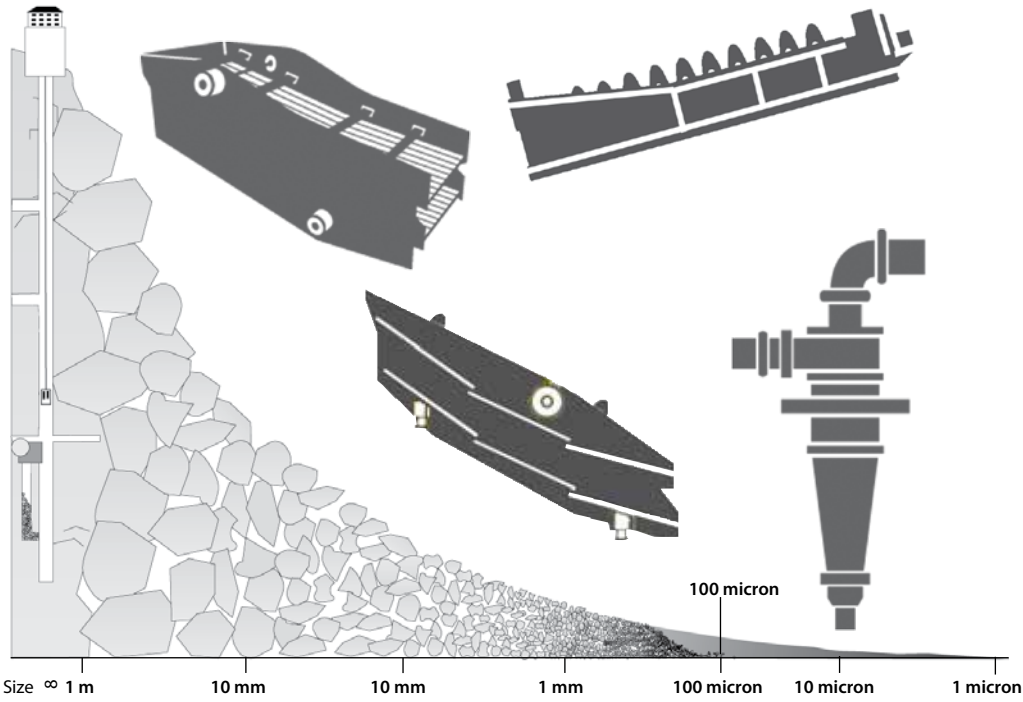
*The equipment shown below is a general application range. The actual range depends on the material properties and process requirements.*



## *Size control*

Neither crushers nor grinding mills are very precise when it comes to the correct sizing of the end products. The reason is to find partly in the variation of the mineral crystals compounds (hard-soft, abrasive – non abrasive), partly in the design and performance of the equipment.

**Size control** is the tool for improvement of the size fractions in the process stages and in the final products.
For the coarser part of the process, screens are used (in practise above 1-2 mm).
In the finer part we have to use classification with spiral classifiers, see section 4.




## *Enrichment – Washing*

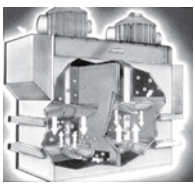
Washing is the simplest method of enrichment used to improve the value of rock and mineral fractions from sand size and upwards. Removing of surface impurities like clay, dust, organics or salts is often a must for a saleable product.
Different techniques are used depending on how hard these impurities are attached to the rock or mineral surface, see section 5.

### *Washing using*

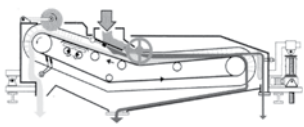
Wet screens*

Scrubbers*

Attrition cells*



Gravity beds*

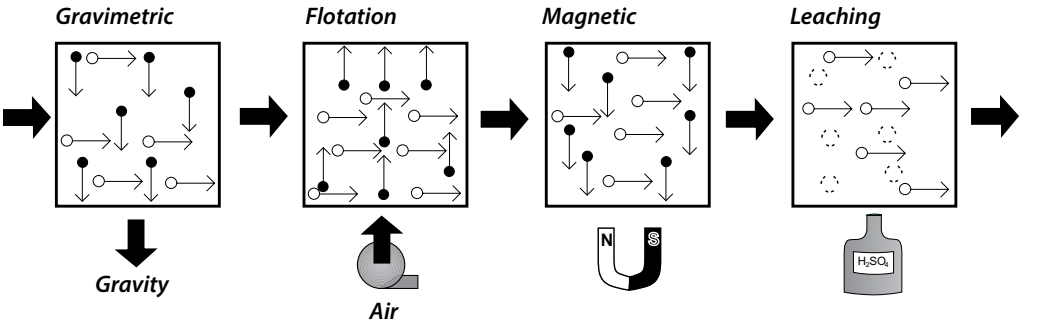


* Contact Metso for further information.

## *Enrichment – Separation*

Most value minerals (both metallic and industrial) are priced by their purity. After liberation by size reduction and size control all minerals are free to be separated from each other.

Depending on the properties of the individual minerals they can be recovered by different methods of separation, see section 5.




• = *value mineral*

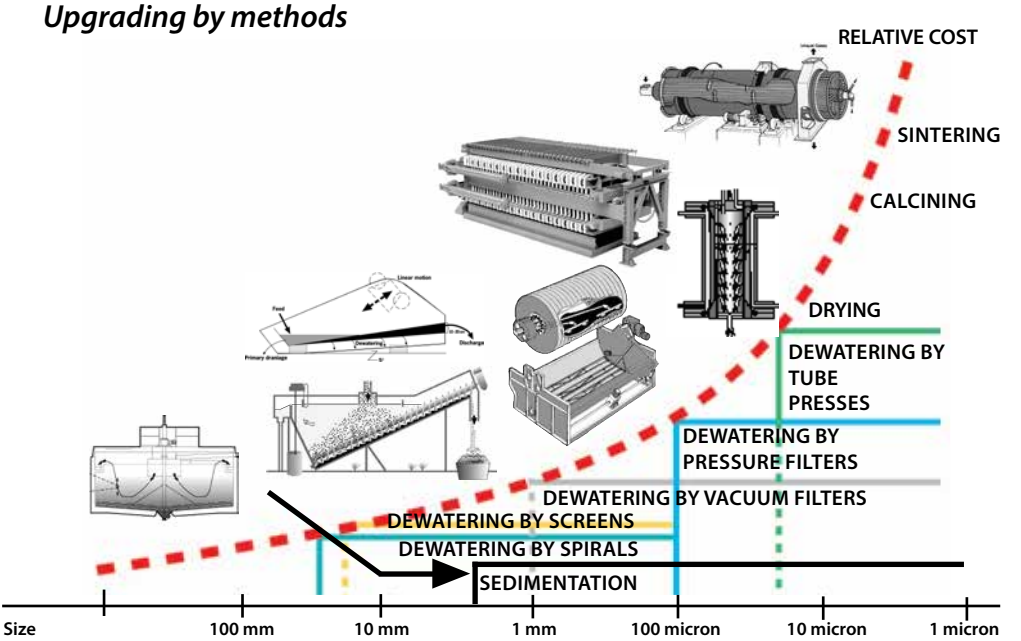
## *Upgrading*

After the enrichment operation we end up with a value product (concentrate) and a non-value product (tailings).

These products are probably not sellable nor disposable due to the content of process water, particle size, or chemical composition.

By upgrading we mean the methods of increasing the value of these products by sedimentation, mechanical dewatering, drying, calcining or sintering and recovering the process water from the tailings, making them disposable, see section 6.

### *Upgrading by methods*



## *Materials handling*

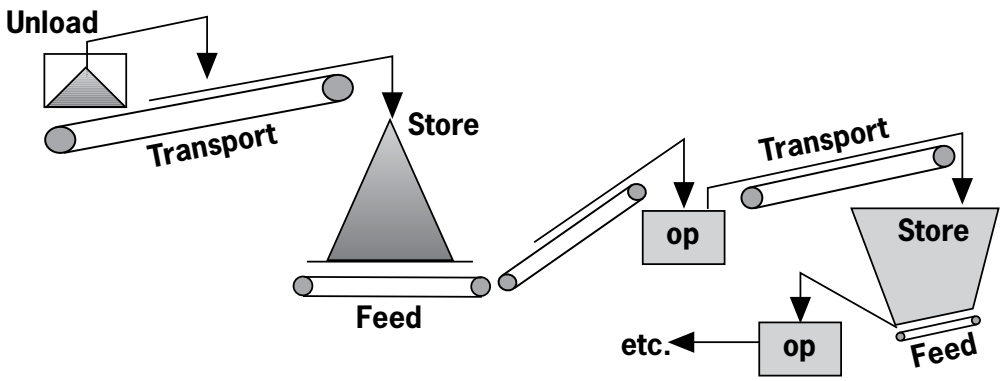
Without a proper set up for materials handling no processing system will perform. Different process stages may be in various locations, may have various feed conditions, are on different shift cycles etc.

**Materials handling** of dry material is based on the operations of loadíng, unloading, transportation, storing and feeding, see section 7.

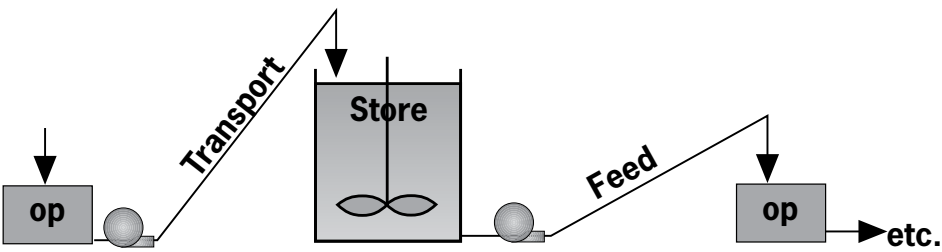
Materials handling of wet material, called **slurry handling** is also based on the operations of transportation (by slurry pumps and hoses), feeding (by slurry pumps) and storage (by slurry agitation), see section 8.



**Dry handling**




**Slurry handling**

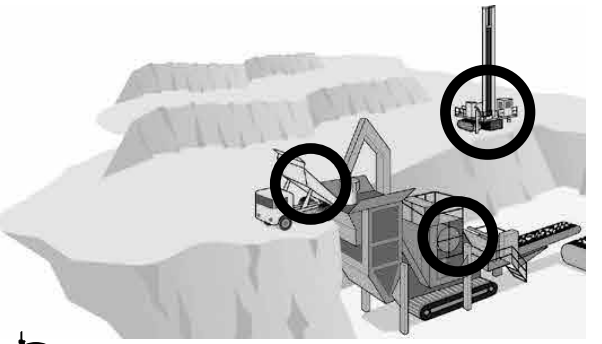


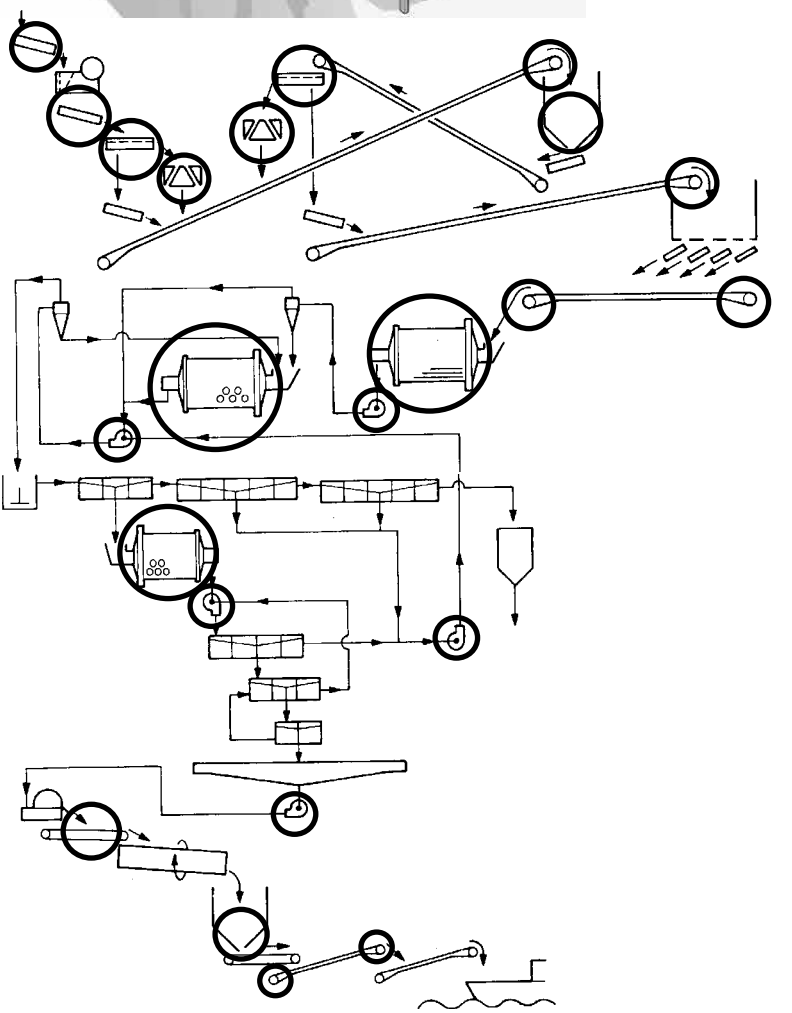
## *Wear in operation*

Whenever energy in any form penetrates rock, ore or mineral, wear will appear.

There is of course a difference whether the minerals are hard or soft, small or large, abrasive or non-abrasive, wet or dry, but wear will always be around.
Both machines and structures must be protected from wear using metals, polymers or compound material.

See section 9, wear in operation.





## *Operation and environment*

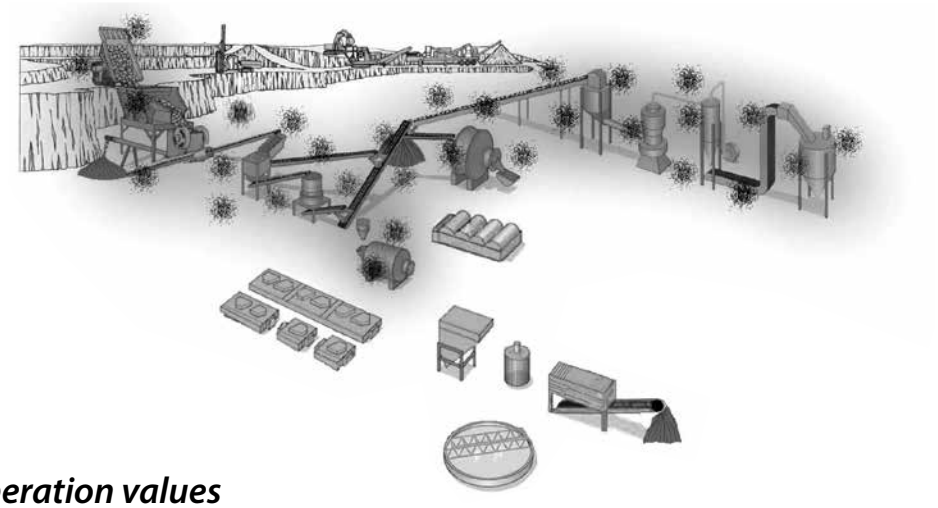
If wear is dangerous for equipment and structures, dust and noise is primarily a danger to the operators.

**Dust** is a problem to both equipment and operators in dry processing

**Noise** is a problem to operators both in wet and dry processing.

By tradition, the environment in mineral processing has a bad reputation.

This is now changing fast due to harder restrictions by law and harder demands from the operators, see section 10, Operation and environment.



## *Operation values*

Prices for products from your operation are seldom set by yourself, but by the market buying them. There is always a possibility to increase the income from your operation by **added values** generated by the operation itself.

- **By improving the output we can increase the product volumes**
- **By improving the quality we can increase the price of our products**
- **By improving the cost control we can reduce our costs of operation**
- **By improving the comfort for our operators we can improve motivation and reduce disturbances in operation**

This can be done by small adjustments, by improved service or by reinvestment in more effective equipment, see all sections.

### *Added value in operation*

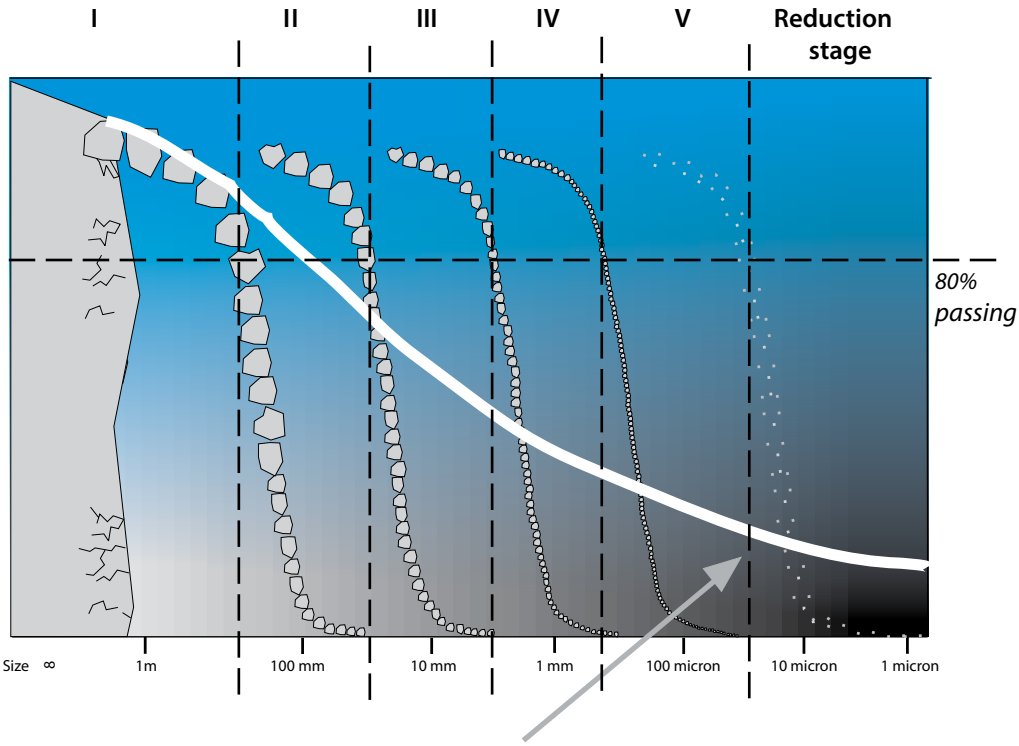
**VOLUME x PRICE – COSTS + MOTIVATION = $**

| Output | Quality | Cost control | Comfort |
|---|---|---|---|
| AVAILABILITY (up time) | SIZE / SHAPE | CAPITAL | SECURITY |
| CAPACITY | PURITY / RECOVERY | ENERGY | ENVIRON-MENT |
| FLEXIBILITY | COMPAC-TION / DENSITY | MATERIAL | RELATIONS |

## *The size reduction process*

Minerals being crystals have a tendency to break into endless numbers of sizes and shapes every time they are introduced to energy. The difficulty in size reduction lays in the art of limiting the number of over and under sizes produced during the reduction. If this is not controlled, the mineral will follow its natural crystal behaviour, normally ending up in over-representation of fines.






*Size reduction behaviour of minerals - by nature*

Note!

There is a large benefit to flotation and separation if there is a steep size distribution of the feed to these processes. So, the trick when producing quality products from rock or minerals (fillers excepted) is to keep the size reduction curves in the later stages as steep as possible. Normally that is what we get paid for – **the shorter or more narrow fraction – the more value!**

To achieve that goal we need to select the correct equipment out of the repertoire for size reduction in a proper way.

They are all different when it comes to reduction technique, reduction ratio, feed size etc. and have to be combined in the optimum way to reach or come close to the requested size interval for the end product.

## Feed material

All operations in size reduction, both crushing and grinding are of course determined by the feed characteristics of the minerals (rock/ore) moving into the circuit. The key parameters we need are the "crushability or grindability", also called **work index** and the "wear profile", called **abrasion index.** Values for some typical feed materials from crushing of rocks, minerals and ore are tabulated below.

### *Impact Work Index $W_i$ kWh/sh.ton*

| Material | Wi value |
|---|---|
| Basalt | 20 ± 4 |
| Diabase | 19 ± 4 |
| Dolomite | 12 ± 3 |
| Iron-ore, Hematite | 13 ± 8 |
| Iron-ore, Magnetite | 12 ± 8 |
| Gabbro | 20 ± 3 |
| Gneiss | 16 ± 4 |
| Granite | 16 ± 6 |
| Greywacke | 18 ± 3 |
| Limestone | 12 ± 3 |
| Quartzite | 16 ± 3 |
| Porphyry | 18 ± 3 |
| Sandstone | 10 ± 3 |
| Syenite | 19 ± 4 |

**INFLUENCING**

• Size reduction • Energy requirement
• Machine status

### *Abrasion index = $A_i$*

| Material | Ai value |
|---|---|
| Basalt | 0,200 ± 0,20 |
| Diabase | 0,300 ± 0,10 |
| Dolomite | 0,010 ± 0,05 |
| Iron-ore, Hematite | 0,500 ± 0,30 |
| Iron-ore, Magnetite | 0,200 ± 0,10 |
| Gabbro | 0,400 ± 0,10 |
| Gneiss | 0,500 ± 0,10 |
| Granite | 0,550 ± 0,10 |
| Greywacke | 0,300 ± 0,10 |
| Limestone | 0,001 – 0,03 |
| Quartzite | 0,750 ± 0,10 |
| Porphyry | 0,100 – 0,90 |
| Sandstone | 0,600 ± 0,20 |
| Syenite | 0,400 ± 0,10 |

**INFLUENCING**

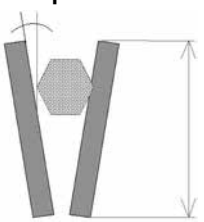
• Wear rate

**Regarding Work Index (Bond) for grinding, see 3:40.**

## Reduction ratio

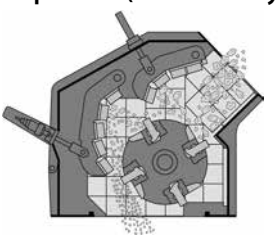
As seen above all size reduction operations are performed in stages. All equipment involved, crushers or grinding mills have different relation between feed and discharge sizes. This is called **reduction ratio.** Typical values below.
Note! High reduction ratio is generally inefficient. For maximum energy efficiency, we recommend multiple stages of grinding

**Compression crushers**



*Jaw 3-4*
*Gyratory 3-5*
*Cone 3-5*

**Impactors (horizontal type)**

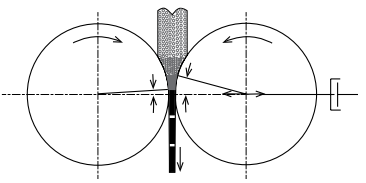


*4-8*

**Impactors (vertical type)**

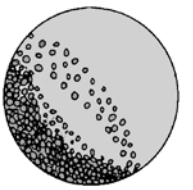
*2-5*

**High pressure grinding rolls**



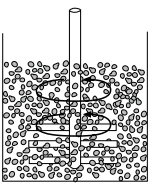
*25*

**Grinding mills (tumbling type)**



*Rod 100*
*Ball 1000*
*AG & SAG 5000*

**Stirred grinding mills**



*100*

## The art of crushing

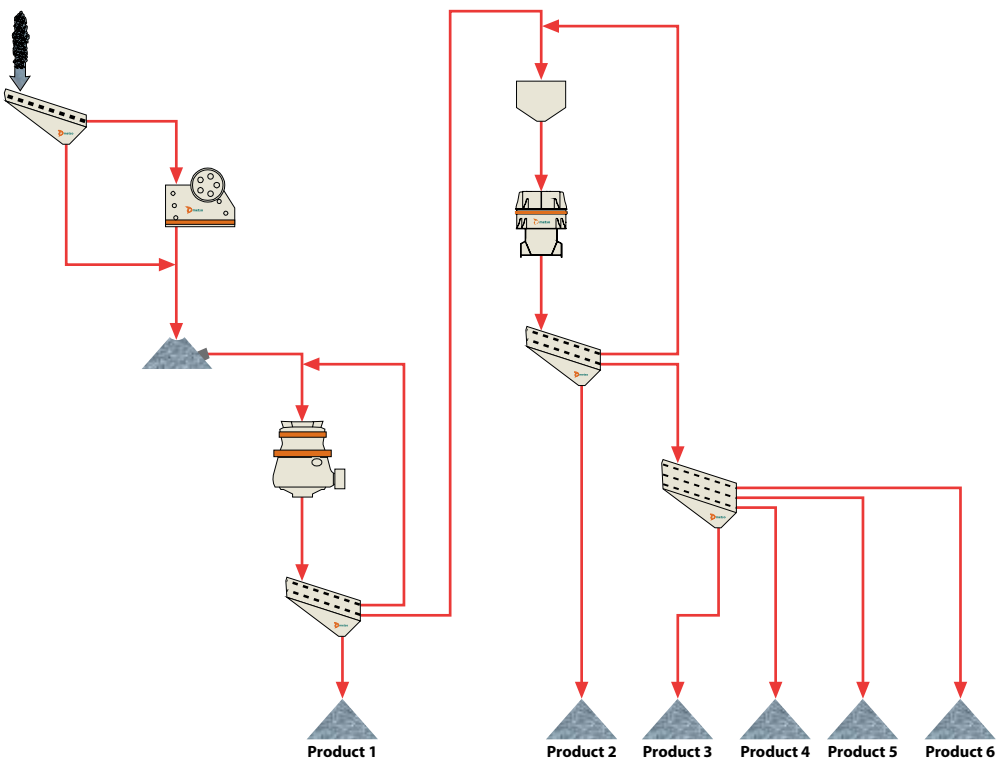
Crushing means different things for different operations and the production goals are not always equal.

| Crushing rock | Crushing gravel | Crushing ore |
|---|---|---|
| Limited reduction | Limited reduction | Maximum reduction |
| Cubical shape | Cubical shape | Shape of no importance |
| Over and undersize important | Over and undersize important | Over and under size of minor importance |
| Flexibility | Flexibility | Flexibility of minor importance |
| Crushing and screening | Less crushing - more screening | More crushing- less screening |
| | | Low production costs High utilisation |



## Crushing of rock and gravel

In the ballast business you are normally paid for short fractions of relatively coarse material with the correct size and shape. Most of the ballast for concrete and asphalt is in the 4 - 18 mm ($^1/_5$ - $^3/_4$") interval.
In order to produce the correct shape and keep over- and under sizes as low as possible this crushing must be done in several stages (3 - 5).

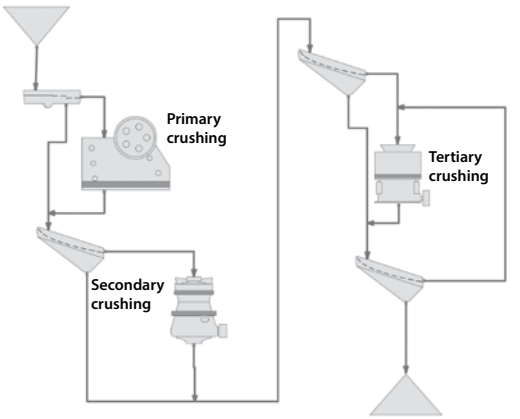


# *Crushing of ore and minerals*

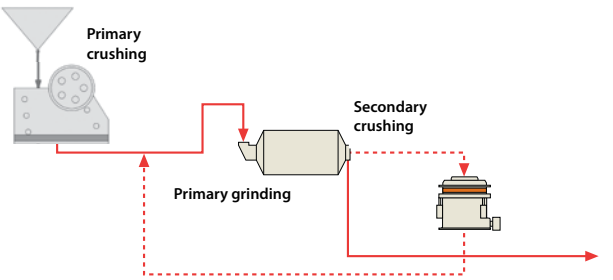
In these operations the value is achieved at the fine end, say below 100 micron (150 mesh).
Normally the size reduction by crushing is of limited importance besides the top size of the product going to grinding.
This means that the number of crushing stages can be reduced depending on the feed size accepted by primary grinding stage.



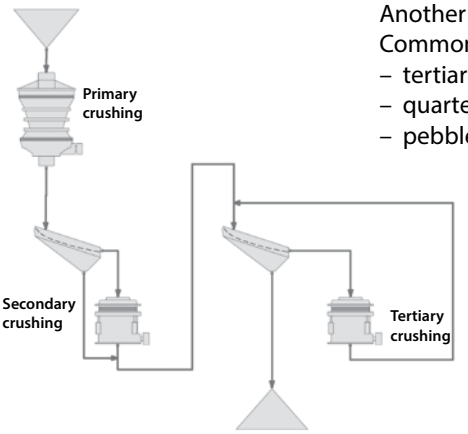
## *"Classical" 3-stage crushing prior to rod mill*




## *Typical 1-2 stage ore crushing in AG-SAG circuit*



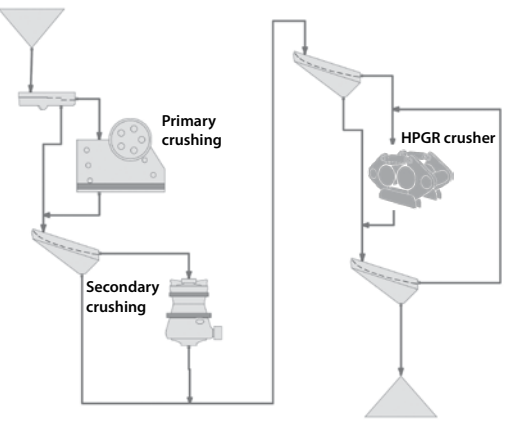

## *Typical 3- stage crushing prior to ball mill*




## *3-stage crushing utilizing an HPGR prior to a rod mill or ball mill*

Another option is including HPGRs in the crushing circuit. Commons circuits include utilizing HPGRs as a:

- tertiary crusher, followed by a ball mill or VERTIMILL®
- quarternary crusher, followed by a ball mill or VERTIMILL®
- pebble crusher in a SABC circuit



## *Crushing – Calculation of reduction ratio*

All crushers have a limited reduction ratio meaning that size reduction will take place in stages. The number of stages is guided by the size of the feed and the requested product, example see below.

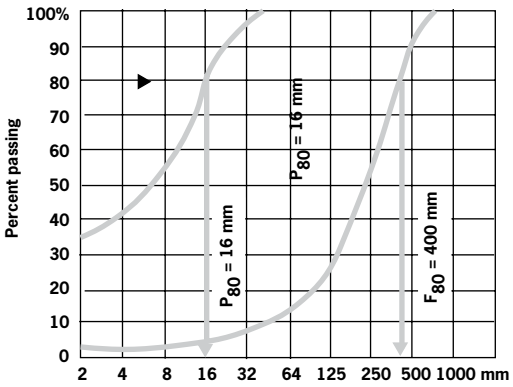
**Feed material size: $F_{80}$ = 400 mm**
Blasted rock, 80% smaller than 400 mm

**Product size: $P_{80}$ = 16 mm**
Road aggregates or rod mill feed 80% smaller than 16 mm

Total reduction ratio (R) $F_{80}/P_{80}$ 400/16 = **25**

Reduction ratio in the primary crushing stage R1 = **3**
Reduction ratio in the secondary crushing stage R2 = **4**

Total in 2 crushing stages gives
R1xR2 = 3x4 = **12**

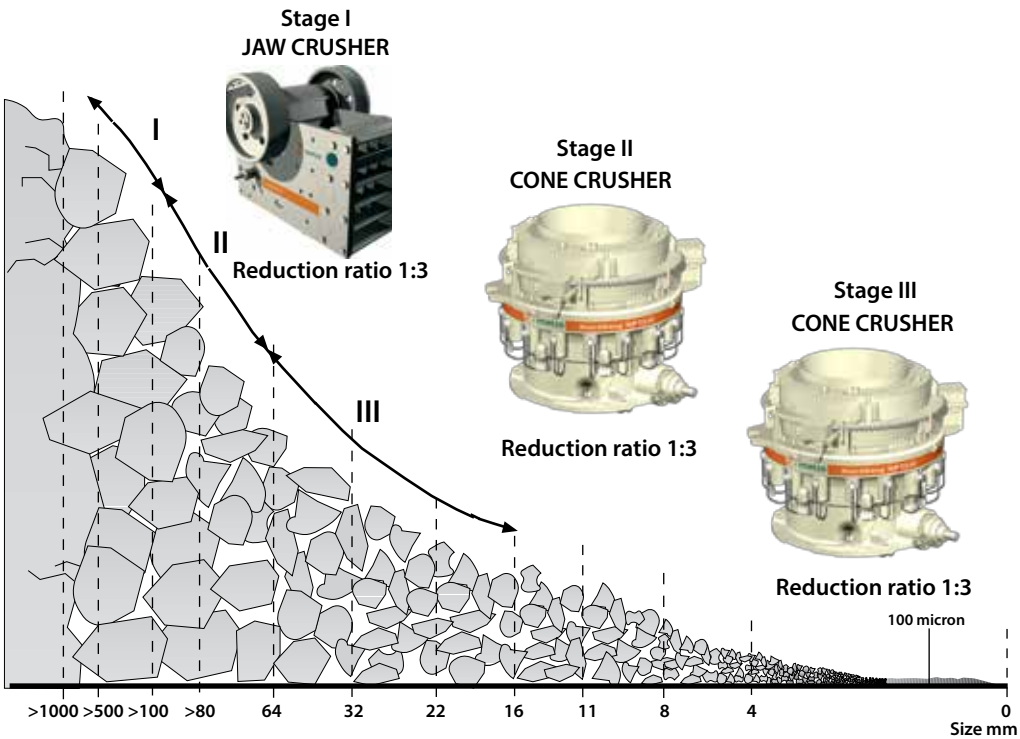



**As we have to use three stages, we can reduce the reduction ratio a bit in every stage, giving more flexibility to the circuit!*

This is not sufficient. We need a third crushing stage.*

For example: Reduction first stage R1 = 3
Reduction second stage R2 = 3
Reduction third stage R3 = 3

Together these three stages give R1xR2xR3 = 3x3x3 = **27** = sufficient reduction




The same size reduction with soft feed (low Bond work index) is done with two stages of HSI (horizontal shaft impactors). With the increased reduction ratio capable in an impactor this process can be achieved in two stages, such as 6:1 and 5:1.

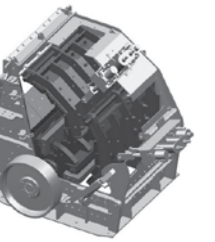
## *Selection of crushers*

Knowing the number of crushing stages we can now start to select the correct crusher for each reduction stage. Depending on operating conditions, feed size, capacity, hardness etc, there are always some options. For primary crushers, see below.

### *Stationary crushers – surface and underground*

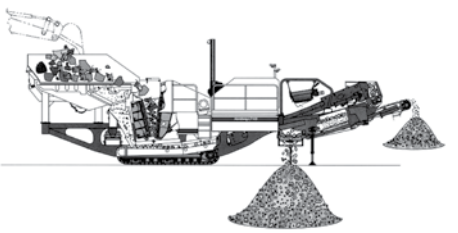
Primary Gyratory

Jaw

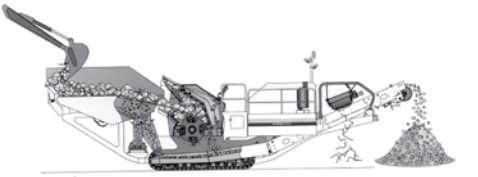


Impact

### *Mobile Crushers*



Jaw + grizzly



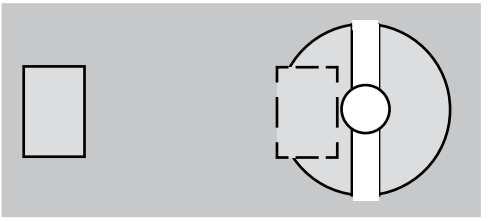
Impact + grizzly

For mobile crushers see further section 11:9

## *Primary crusher – Type*

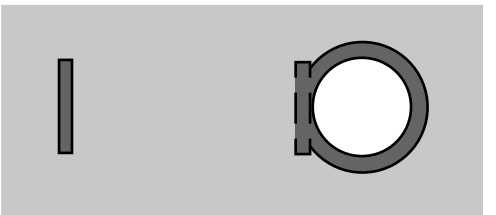
For **soft feed and non-abarasive** feed (low Bond work index) a horizontal Impactor (HSI) is an option if the capacity is not too high.

For **harder feed** there is a choice between a gyratory or a jaw crusher, see below.



*Feed opening Jaw crusher*

*Feed opening Gyratory crusher*



*Discharge opening Jaw crusher*

*Discharge opening Gyratory crusher*

Note: HSI can be used only if the abrasion index is lower and the plant does not mind fines production. Otherwise, a jaw crusher is preferred for lower capacity aggregate plants.)

***Rule 1:*** *Always use a jaw crusher if you can, jaws are the least capital cost.*

***Rule 2:*** *For low capacity use jaw crusher and hydraulic hammer for oversize.*

***Rule 3:*** *For high capacities (800-1500 tph) use jaw crusher with big intake opening.*

***Rule 4:*** *For very high capacities (1200+ tph use gyratory crusher.*

# Primary crusher – Sizing

Crushers are normally sized from top size of feed. At a certain feed size, knowing the capacity, we can select the correct machine, see below.

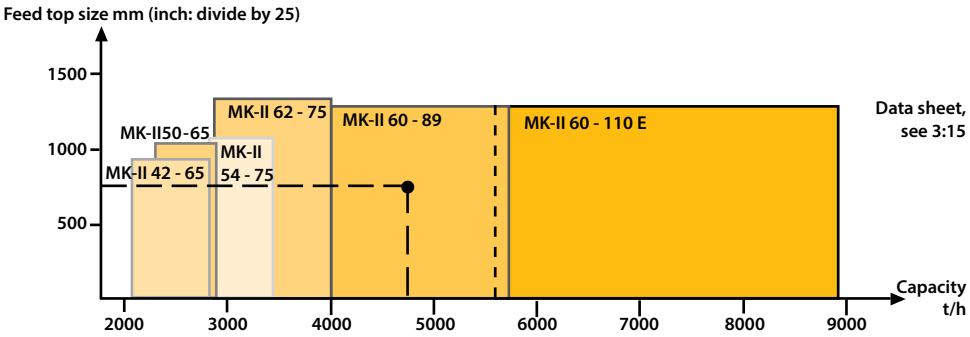
A correct sizing of any crusher is not easy and the charts below can only be used for guidance.

***Ex. Feed is a blasted hard rock ore with top size 750 mm. Capacity is 4750 t/h.***

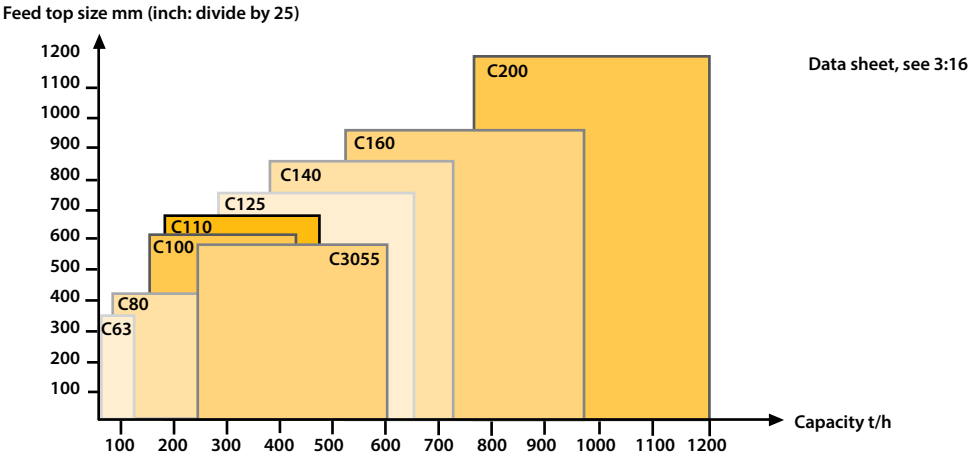
- *Which primary crusher can do the job?*
- *Check on the two compression machines below and take out the sizing point!*
- *Correct selection is Superior® MK-II Primary Gyratory Crusher type MK-II 60-89*



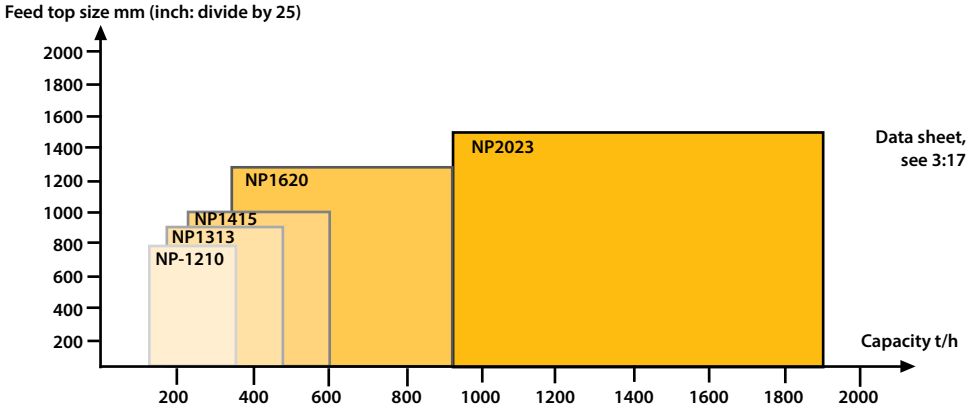
## Primary gyratory – Feed size vs capacity




## Primary jaw crusher – Feed size vs capacity




## Primary impactor – Feed size vs capacity



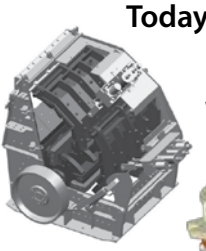
## *Secondary crusher – Type*

In a **rock crushing circuit,** the second stage normally starts to be of importance for control of size and shape.
Because of this the jaw crusher, in most cases, is disqualified as secondary crusher. Instead the cone crusher is used more frequently.
Also in comminution (crushing and grinding) circuits for ore and minerals the cone crusher is frequently used as the secondary stage, see 3:4.

Using a secondary HSI means as always a restriction in feed hardness and abrasiveness.

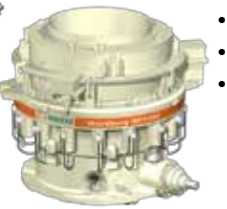
**Yesterday** **Today** **Demands**

**Jaw Crusher**



**HSI**

**Limitations in**
**$W_i$ and $A_i$**



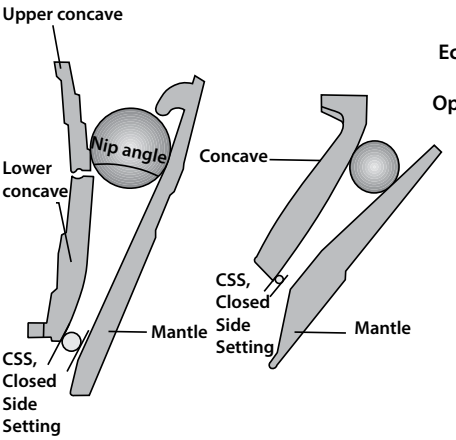
**Cone Crusher**

- **Big feed opening**
- **High capacity**
- **Controlled feed**
- **Shape**

## *Cone crusher – A powerful concept*

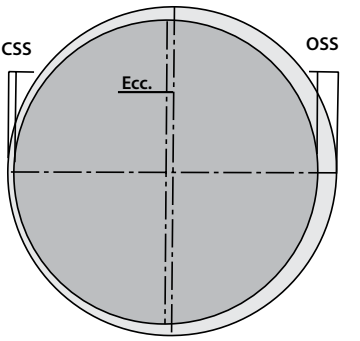
Compared to other crushers the cone crusher has some advantages making them very suitable for size reduction and shaping downstream a crushing circuit. Reason is the crushing chamber and the possibilities to change feed and discharge openings during operation.

**Chamber geometry**




**Closed side setting (CSS)**
**+**
**Eccentric setting (Ecc.)**
**=**
**Open side setting (OSS)**

**Chamber settings**

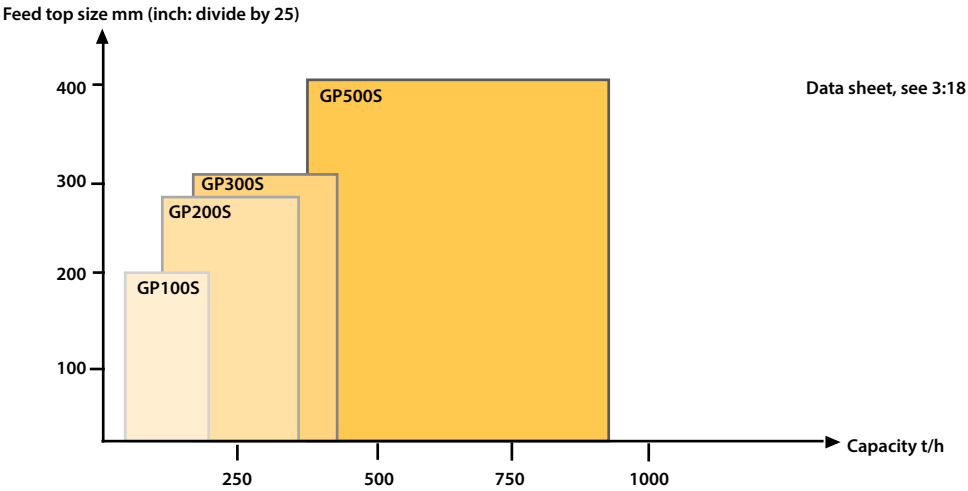



- Chamber intake to match feed size
- Each machine size has different chamber options (other crusher types have not)
- Each chamber has a certain feed size vs capacity relation
- Increased Ecc. (at the same CSS) will give higher capacity.
- Decreased CSS will improve reduction but will also reduce capacity and increase risk for packing

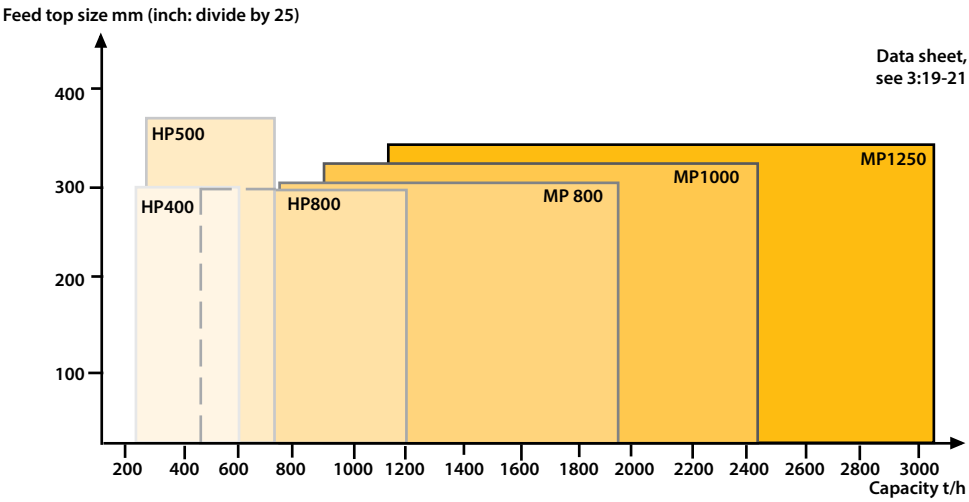
**Approx. size of discharge:**
From Cone 70-80%<CSS
From Gyratory 85-95%<OSS

# Secondary crushers – Sizing

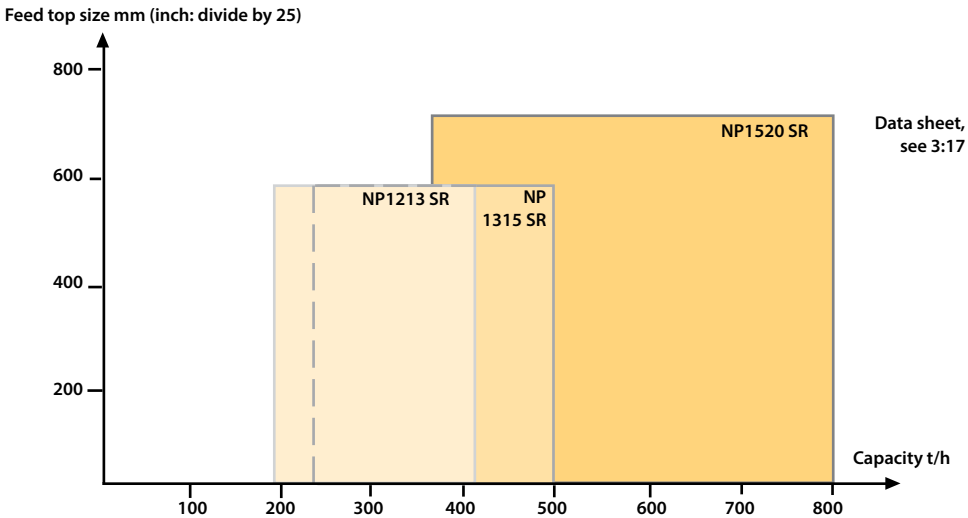
## Secondary crushers – Feed size vs capacity (GPS range)




## Cone crusher – Feed size vs capacity (HP and MP range)




## Secondary impactor – Feed size vs capacity



## Final crushing stage – More than just crushing

For many rock and gravel crushing circuits the final crushing stage is of special interest.

The final sizing and shaping will take place in this stage influencing the value of the final product.

For hard, abrasive rock circuits Cone crushers, Vertical Shaft Impactors (VSI) or High Pressure Grinding Rolls (HPGRs) can be used.



### Most common

Cone crusher VSI HPGR

| Demands | Variables |
|---|---|
| Max feed size | Crushing chamber |
| Capacity | Size of crusher |
| Product shape | Setting / speed |

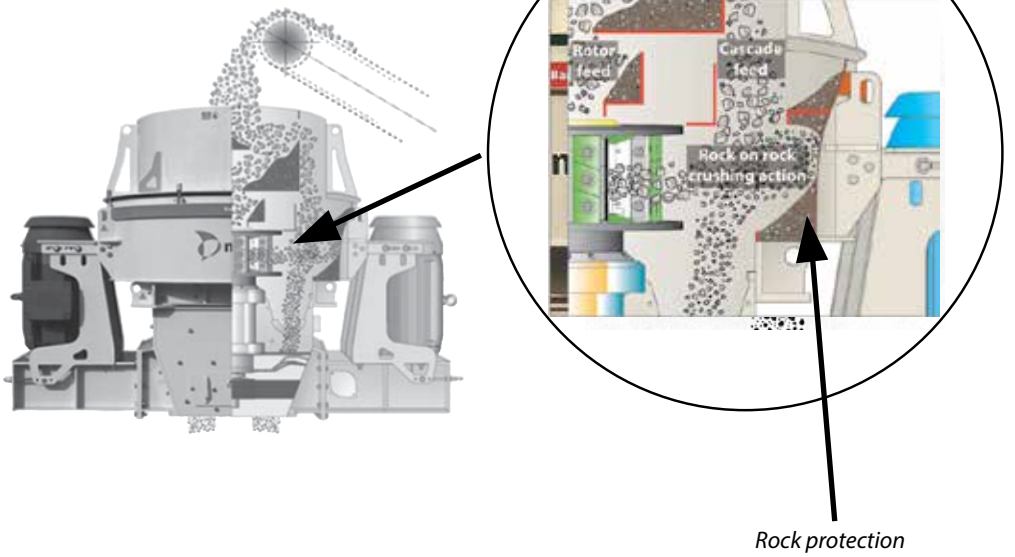
## VSI – A rock on rock autogeneous crushing impactor

Horizontal impactors normally use rock to metal impaction. This means a restriction in crushing circuits with hard feed material, when wear can be dramatically high.

The VSI Impactor of Barmac type is using a **rock-to-rock** impaction technology where most of the design is protected by rock, see below. This means that we can use the advantages of the impaction techniques also in hard, abrasive rock operations.

The crushing action takes place in the "rock cloud" in the crushing chamber, not against the rock protection.

### VSI – function



## *High Pressure Grinding Rolls (HPGRs) - HRC™*

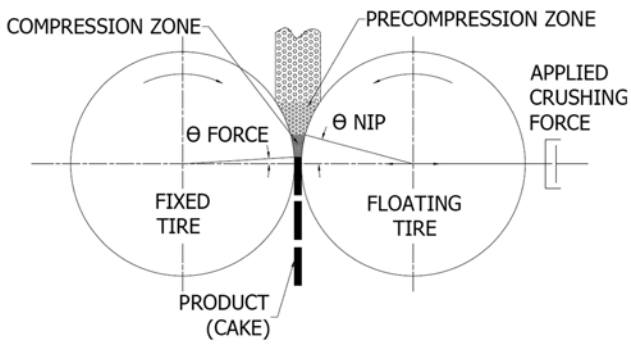
HPGRs utilize two counter-rotating tires – one fixed and one floating – in order to effectively crush ore. Hydraulic cylinders apply very high pressure to the system, causing inter-particle comminution as the feed travels between the two tires.

The basic operating principle behind HPGRs makes them very energy efficient:

The feed is introduced to the crushing zone, where high pressure is applied to the bed of material in a highly controlled manner.

- Dry
- Size reduction through compression, controlled application of pressure – energy efficient
- Open or closed circuit
- Flexible operating parameters (speed and pressure)
- No use of grinding media
- Short retention time
- Feed size restricted by operating gap, minus 90 mm depending on unit size
- Low noise level
- Low operating cost

Data sheet, see 3:24

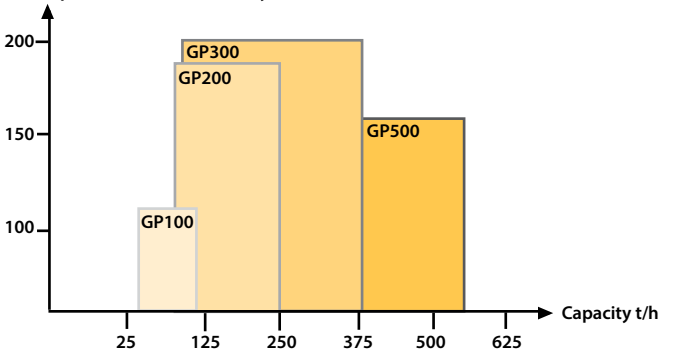


# *Final crusher – Sizing*

## *Tertiary cone crushers – GP* series – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

*Feed top size at minimum setting 10 mm and coarse liner profile

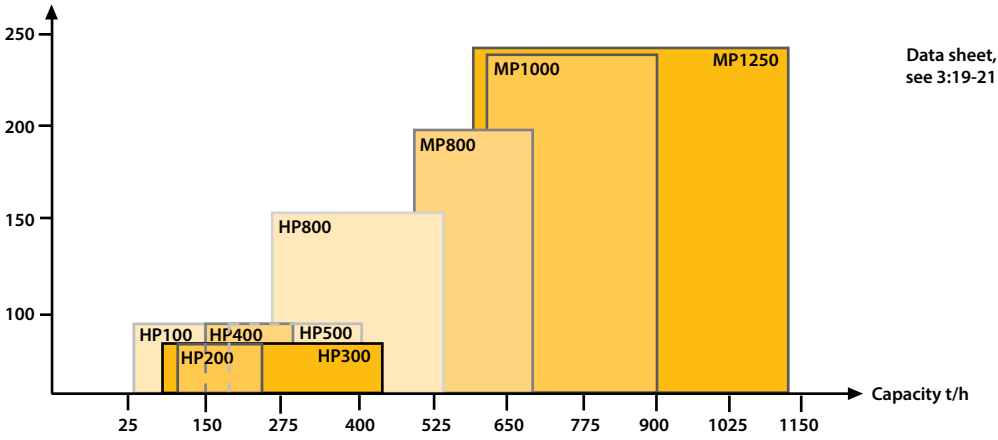



Data sheet, see 3:22

## *Tertiary cone crushers – HP* and MP* series – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

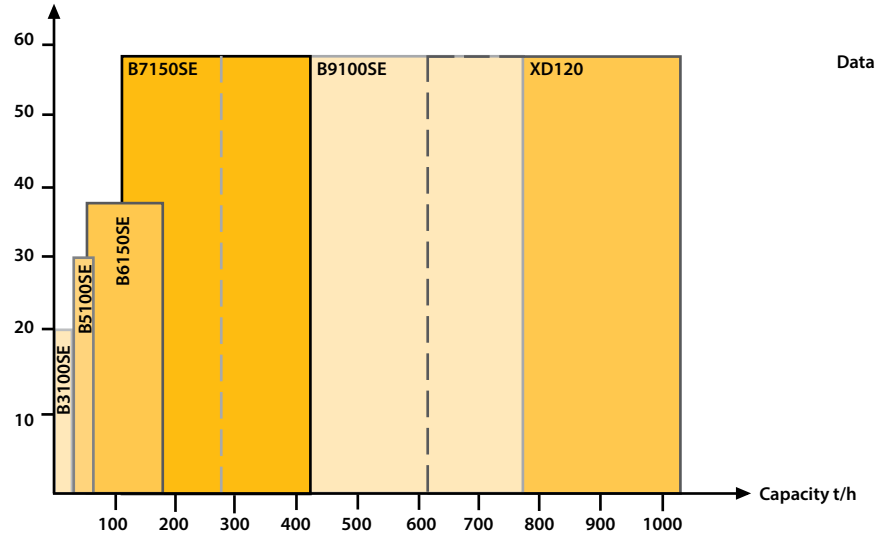
*Feed top size at 19 mm setting for HP 800, MP 800 - 1250




Data sheet, see 3:19-21

## *VSI crusher – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

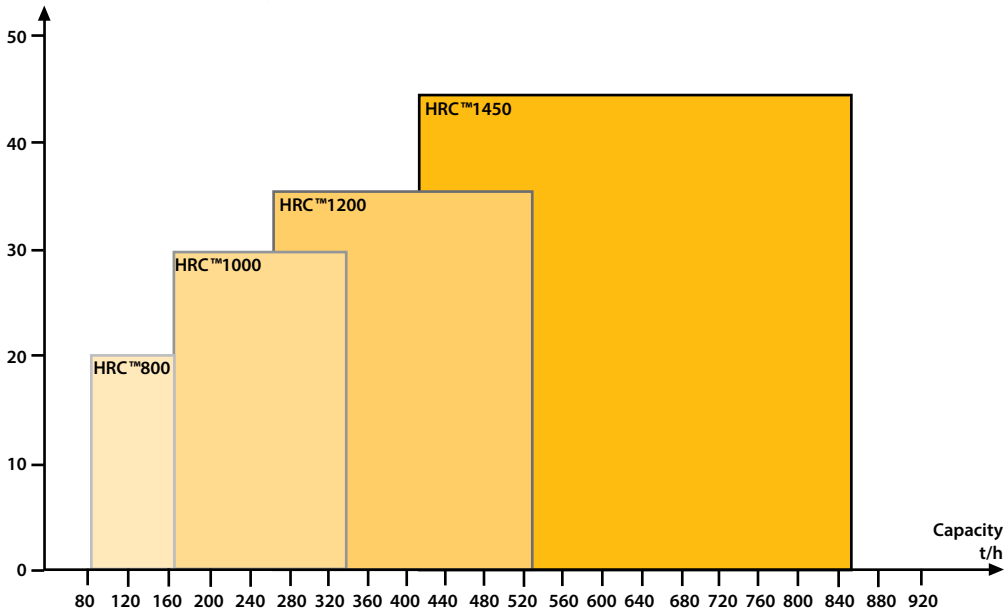



Data sheet, see 3:23

## *HPGR - HRC™ 800 - 1450 – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

Data sheet, see 3:24

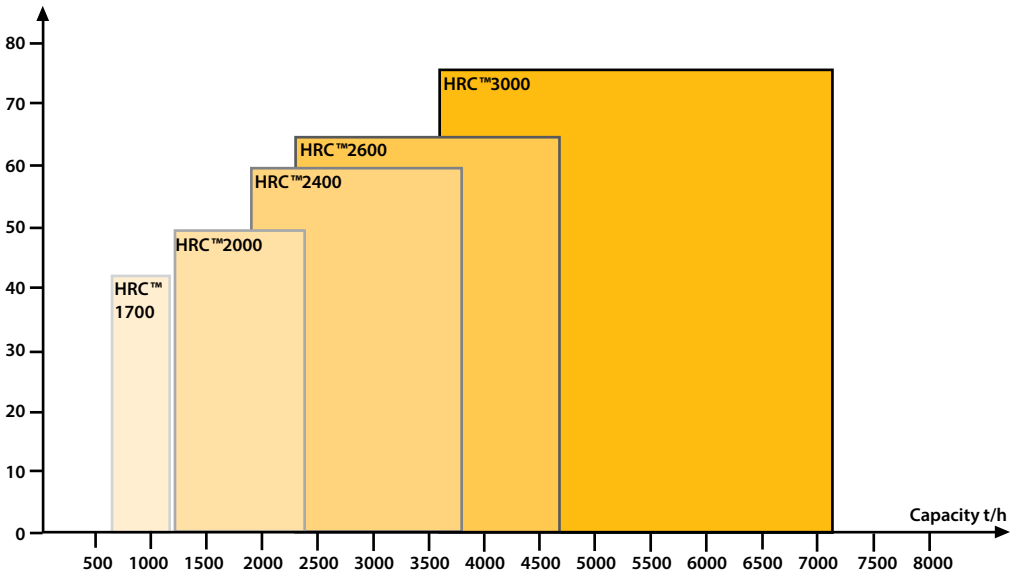





## *HPGR - HRC™ 1700 - 3000 – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

Data sheet, 3:24

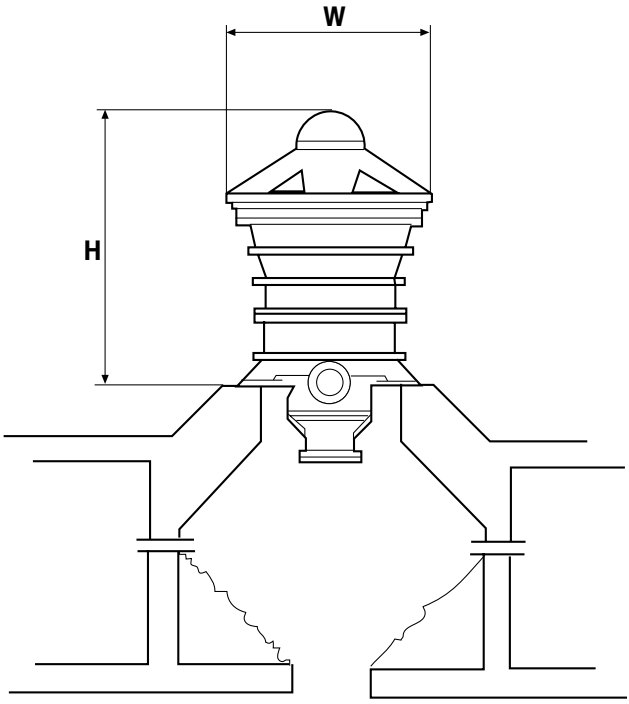


## *Wet crushing prior to grinding**

**WaterFlush** is a patented wet crushing process for producing a flakier finer product from specially designed cone crushers. The method is intended for mining applications comprising secondary crushing, sand manufacturing and fine crushing of ore prior to leaching. The typically crusher discharge is a slurry of 30 to 70% solids. The flakier feed brakes easily in the following grinding mill. WaterFlush can be an alternative to conventional crushing prior to grinding in applications with critical-size-build-up problems in the grinding circuits of type AG/SAG and Pebble mill, see grinding page 3:26-27.

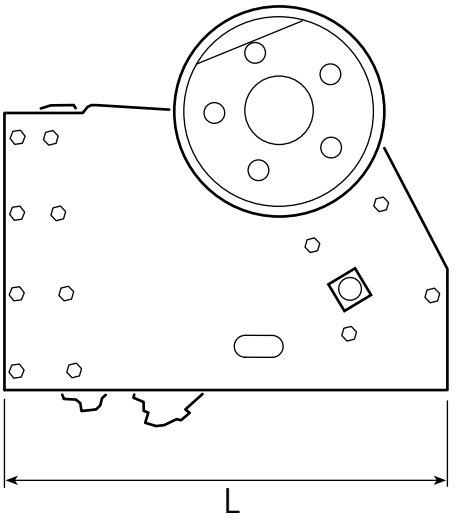
*Not available from Metso

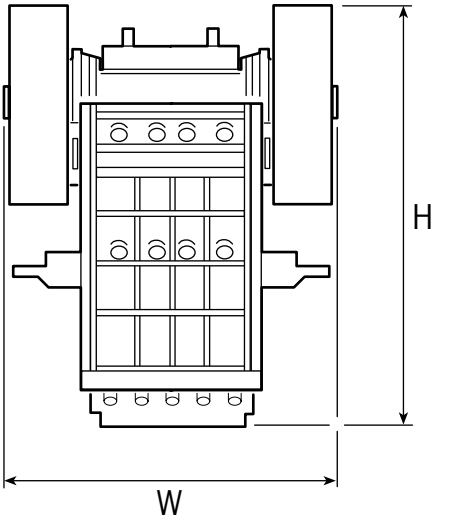
## *Gyratory crusher – SUPERIOR® MK-II Primary*




| Type | H mm (inch) | W mm (inch) | Weight mt (U.S. t) | Max. power kW (Hp) |
|---|---|---|---|---|
| MK-II 42-65 | 4807 (189.3) | 3937 (155.0) | 120 (132) | 375 (500) |
| MK-II 50-65 | 5513 (217.0) | 4458 (175.5) | 153 (168) | 375 (500) |
| MK-II 54-75 | 5957 (234.5) | 4928 (194.0) | 242 (266) | 450 (600) |
| MK-II 62-75 | 6633 (261.1) | 5574 (219.4) | 299 (328) | 450 (600) |
| MK-II 60-89 | 7474 (294.3) | 5588 (220.0) | 398 (438) | 600 (800) |
| MK-II 60-110E | 7518 (296.0) | 6197 (244.0) | 553 (609) | 1200 (1600) |

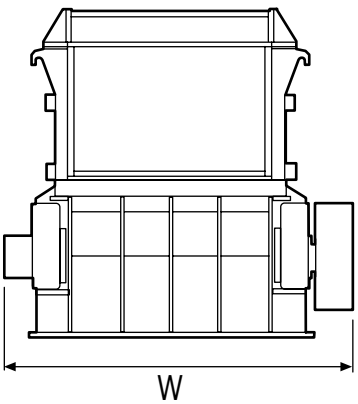
## *Jaw crusher – C series*

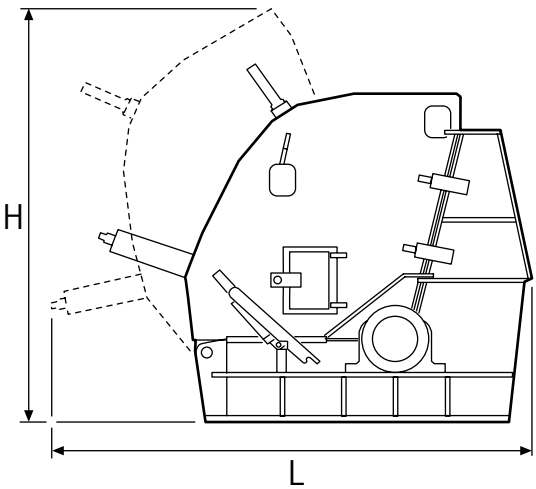



| Type | H mm (inch) | L mm (inch) | W mm (inch) | Weight mt (US ton) | kW/Hp Max. power |
|---|---|---|---|---|---|
| C 63 | 1 600 (63) | 1 950 (77) | 1 390 (55) | 5 (6) | 45/60 |
| C 80 | 1 700 (67) | 2 020 (80) | 1 565 (62) | 7 (8) | 75/100 |
| C 100 | 2 400 (95) | 2 880 (113) | 2 250 (89) | 18 (20) | 110/150 |
| C 105 | 2 050 (81) | 2 630 (104) | 1 920 (76) | 13 (14) | 110/150 |
| C 110 | 2 670 (105) | 2 830 (112) | 2 385 (94) | 23 (25) | 160/200 |
| C 125 | 2 900 (114) | 3 370 (133) | 2 690 (106) | 33 (36) | 160/200 |
| C 140 | 3 060 (121) | 3 645 (144) | 2 890 (114) | 41 (45) | 200/250 |
| C 145 | 3 330 (131) | 3 855 (152) | 2 870 (113) | 49 (54) | 200/250 |
| C 160 | 3 550 (140) | 4 200 (165) | 3 180 (125) | 63 (69) | 250/300 |
| C 200 | 4 220 (166) | 4 870 (192) | 3 890 (153) | 107 (118) | 400/500 |
| C 3055 | 2 400 (95) | 2 920 (115) | 2 550 (100) | 24 (26) | 160/200 |

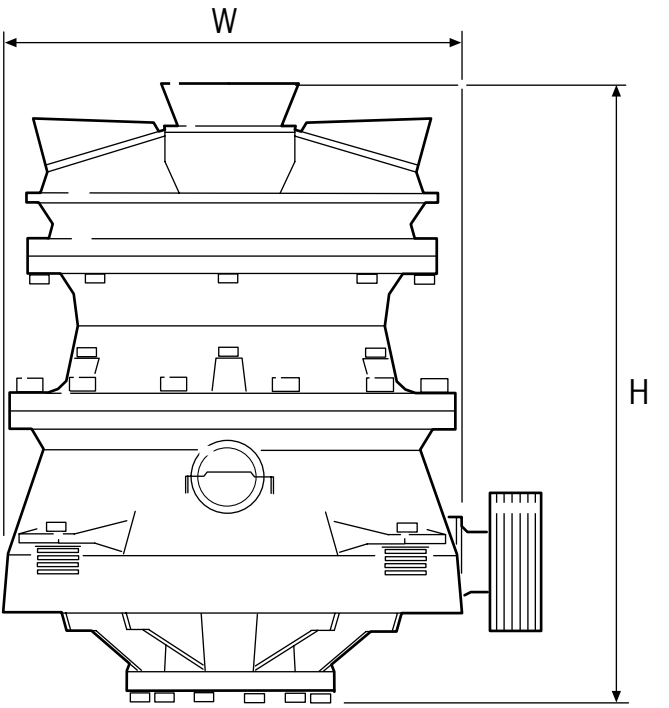
## *Impact crusher – NP series*



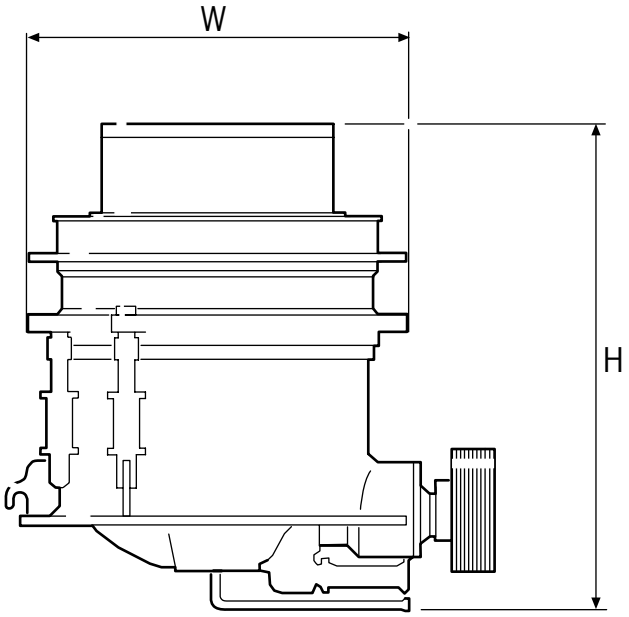

| Type | H mm (inch) | L mm (inch) | W mm (inch) | Weight mt (US ton) | kW/Hp Max. power |
|---|---|---|---|---|---|
| NP 1110 | 2 716 (107) | 3 487 (137) | 2 106 (83) | 8 (9) | 250/350 |
| NP1213 | 2 882 (114) | 3 875 (153) | 2 529 (100) | 12 (13) | 315/400 |
| NP1315 | 3 055 (120) | 4 030 (159) | 2 750 (108) | 15 (16) | 500 (2x250)/700 (2x350) |
| NP1520 | 3 540 (139) | 4 703 (186) | 3 400 (134) | 24 (27) | 1200 (2x600)/1600 (2x800) |
| | | | | | |
| NP 1313 | 3 405 (134) | 3 396 (134) | 2 560 (101) | 16 (18) | 200/250 |
| NP 1415 | 3 600 (142) | 3 395 (134) | 2 790 (110) | 20 (22) | 250/350 |
| NP 1620 | 4 400 (173) | 3 935 (155) | 3 600 (142) | 36 (40) | 315/400 |
| NP 2023 | 5 700 (224) | 5 040 (198) | 4 330 (171) | 67 (74) | 500 (2x250)/700 (2x350) |

## *Cone crusher – GPS series*




| Type | H mm (inch) | W/L mm (inch) | Weight MT (US ton) | kW/Hp Max. power |
|---|---|---|---|---|
| GP100S | 2 328 (92) | 1 300 (51) | 7 (8) | 90/125 |
| GP200S | 2 461 (97) | 1 745 (69) | 10 (11) | 160/250 |
| GP300S | 2 546 (100) | 1 858 (73) | 15 (16) | 250/350 |
| GP500S | 3 227 (127) | 2 300 (91) | 29 (32) | 315/400 |

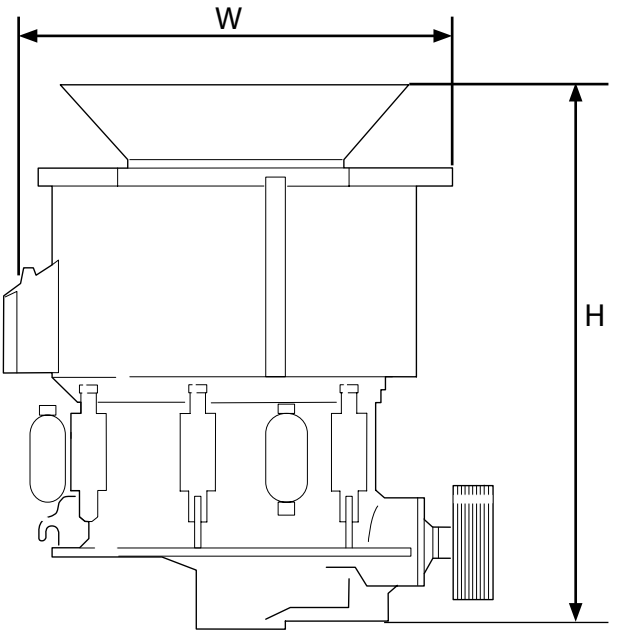
## *Cone crusher – HP series*



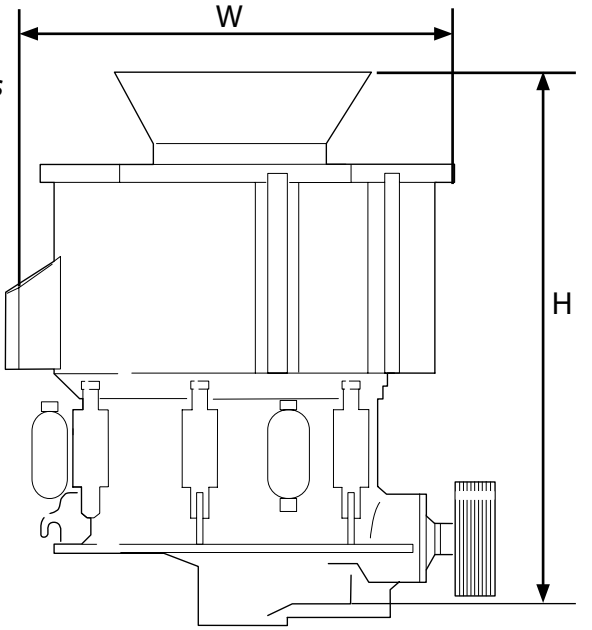

| Type | H mm (inch) | W mm (inch) | Weight mt (U.S. t) | Max. power kW (Hp) |
|---|---|---|---|---|
| HP 800 | 4 057 (160) | 3 490 (137) | 69 (76) | 600 (800) |

## *Cone crusher – HP 3, 4 and 5 series*

*Cone crusher HP 3 series*



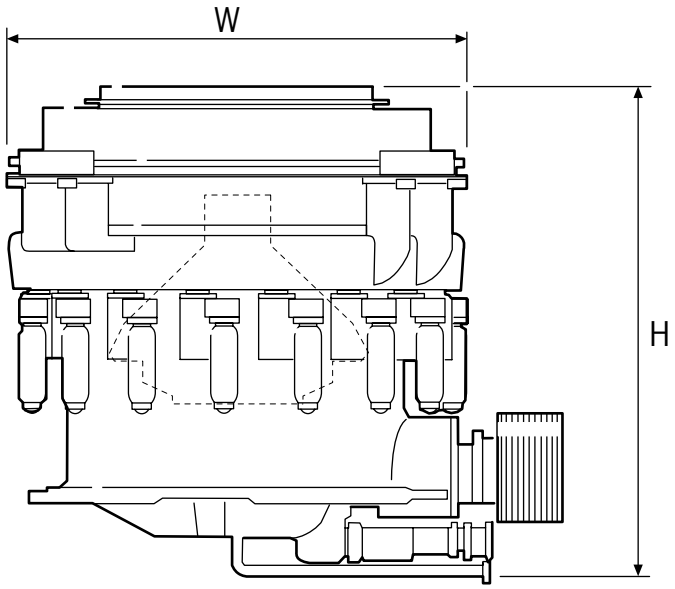

*Cone crusher HP 4 & 5 series*




| Type | H mm (inch | W mm (inch | Weight kg (lbs) | Weight complete* | Max. power kW (Hp) |
|---|---|---|---|---|---|
| HP3 | 2 817 (111) | 2 778 (109 | 13 280 (29 277) | 16 446 (36 257) | 220 (300 hp) |
| HP4 | 2 549 (100) | 2 955 (116) | 19 810 (43 586) | 23 672 (52 084) | 315 (400) |
| HP5 | 3 953 (156) | 3 854 (152) | 33 000 (73 000) | 44 500 (98 200) | 450 (600) |

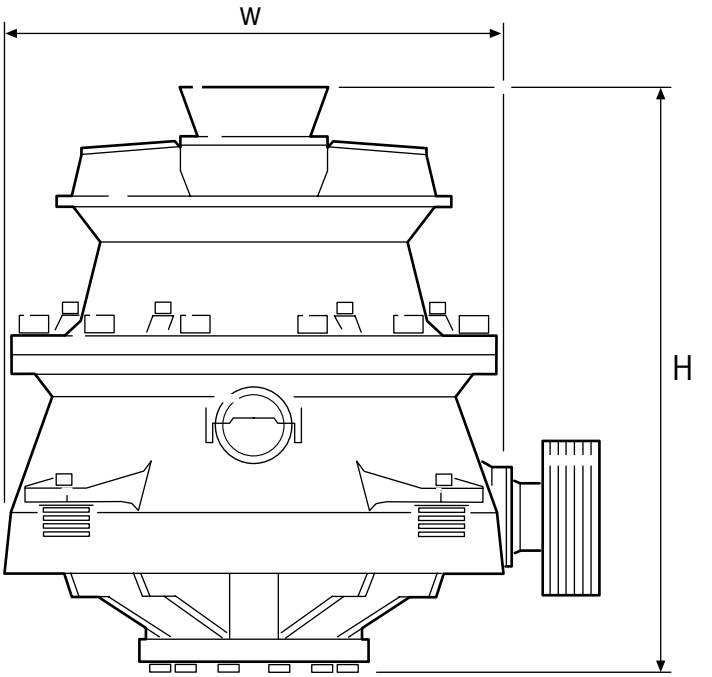
* Complete crusher weight: crusher + subframe, motor, sub frame, covers, feed and discharge arrangement

## *Cone crusher – MP series*



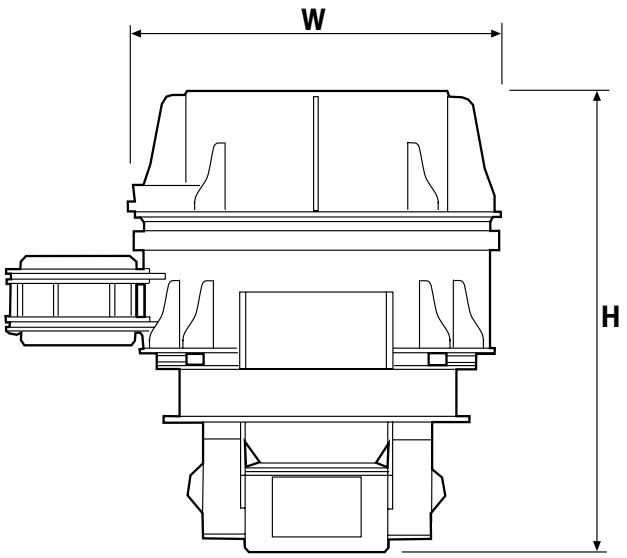

| Type | H mm (inch) | W mm (inch) | Weight mt (U.S. t) | Max. power kW (Hp) |
|---|---|---|---|---|
| MP800 | 4622 (182.0) | 4550 (179.1) | 121 (133) | 600 (800) |
| MP1000 | 4663 (183.6) | 5360 (211.0) | 151 (166) | 750 (1000) |
| MP1250 | 4663 (183.6) | 5360 (211.0) | 153 (168) | 900 (1250) |

## *Cone crusher – GP series*




| Type | H mm (inch) | W/L mm (inch) | Weight MT (US ton) | kW/Hp Max. power |
|---|---|---|---|---|
| GP100 | 2 038 (80) | 1 300 (51) | 5 (6) | 90/124 |
| GP200 | 2 230 (84) | 1 735 (68) | 8 (9) | 110/160 |
| GP300 | 2 181 (86) | 1 860 (73) | 12 (13) | 250/300 |
| GP500 | 2 573 (101) | 2 240 (88) | 21 (23) | 300/400 |

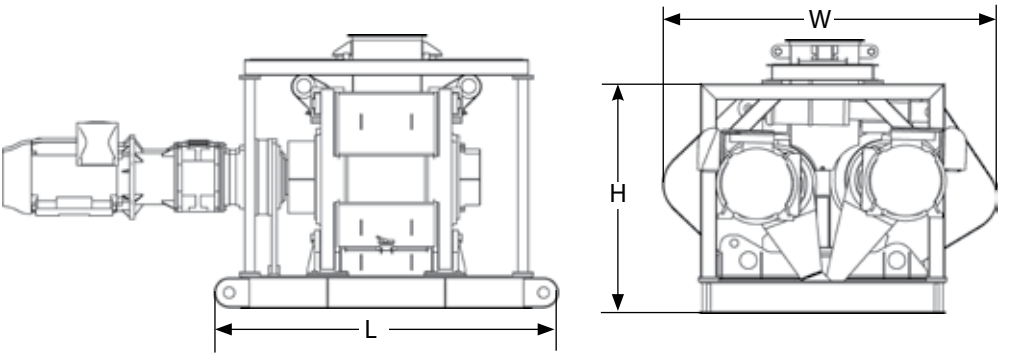
## *Vertical shaft impactor (VSI)*



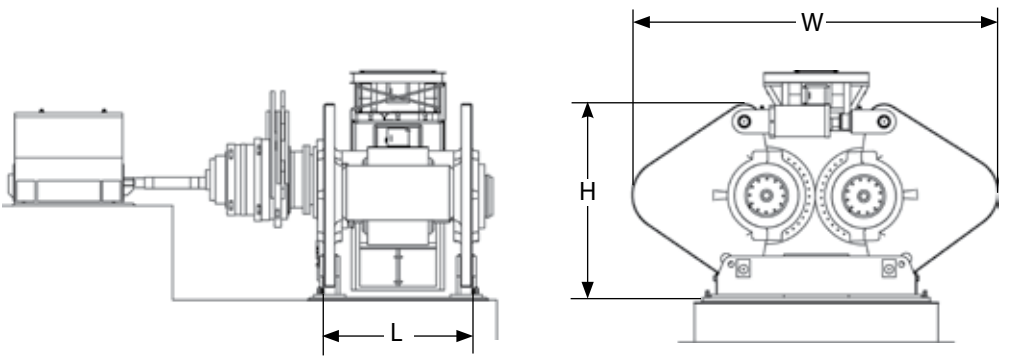

| Type | H mm (inch | W mm (inch | Weight MT (US ton) | kW/Hp Max. power |
|---|---|---|---|---|
| B3100SE | 1 171 (46) | 940 (37) | 0,9 (1) | 15/20 |
| B5100SE | 1 705 (67) | 1 435 (56) | 2,7 (3) | 55/75 |
| B6150SE | 2 189 (86) | 1 870 (74) | 4,5 (5) | 150/20 |
| B7150SE | 2 464 (97) | 2 220 (87) | 10 (11) | 300/400 |
| B9100SE | 2 813 (111) | 2 434 (96) | 12 (13) | 600/800 |
| XD120 | 4 211 (166) | 3 110 (122) | 21 (23) | 800/1075 |

## *High Pressure Grinding Rolls (HPGRs) - HRC™*






| Model | Tire dimensions mm | Max. motor power kW | Max. motor power HP | H mm (inch) | L mm (inch) | W mm (inch) |
|---|---|---|---|---|---|---|
| HRC™800 | 730 x 500 | 2 x 132 kW | 2 x 177 HP | 2400 (94) | 3700 (146) | 2700 (106) |
| HRC™1000 | 1000 x 625 | 2 x 260 kW | 2 x 349 HP | 2700 (106) | 3520 (139) | 3500 (138) |




| Model | Tire dimensions mm | Max. motor power kW | Max. motor power HP | H mm (inch) | L mm (inch) | W mm (inch) |
|---|---|---|---|---|---|---|
| HRC™1200 | 1200 x 750 | 2 x 440 kW | 2 x 590 HP | 2200 (87) | 1610 (639) | 4400 (173) |
| HRC™1450 | 1450 x 900 | 2 x 650 kW | 2 x 872 HP | 3556 (140) | 2050 (81) | 5196 (205) |
| HRC™1700 | 1700 x 1000 | 2 x 900 kW | 2 x 1207 HP | 3730 (147) | 3690 (145) | 6240 (246) |
| HRC™2000 | 2000 x 1650 | 2 x 2300 kW | 2 x 3084 HP | 5309 (209) | 6079 (239) | 9512 (375) |
| HRC™2400 | 2400 x 1650 | 2 x 3000 kW | 2 x 4023 HP | 6646 (262) | 3630 (143) | 9092 (358) |
| HRC™2600 | 2600 x 1750 | 2 x 3700 kW | 2 x 4962 HP | 6030 (237) | 5660 (223) | 9380 (369) |
| HRC™3000 | 3000 x 2000 | 2 x 5700 kW | 2 x 7644 HP | 6937 (273) | 6480 (255) | 10800 (425) |

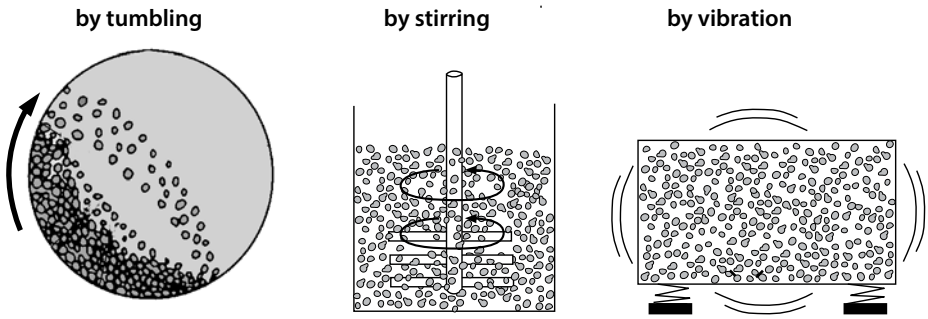
## Grinding – Introduction

Size reduction by crushing has a size limitation for the final products. If we require further reduction, say below 5-20 mm, we have to use the processes of grinding. Grinding is a **powdering or pulverizing** process using the rock mechanical forces of impaction, compression, shearing and attrition.
The two main purposes for a grinding process are:

- *To liberate individual minerals trapped in rock crystals (ores) and thereby open up for a subsequent enrichment in the form of separation.*
- *To produce fines (or filler) from mineral fractions by increasing the specific surface.*



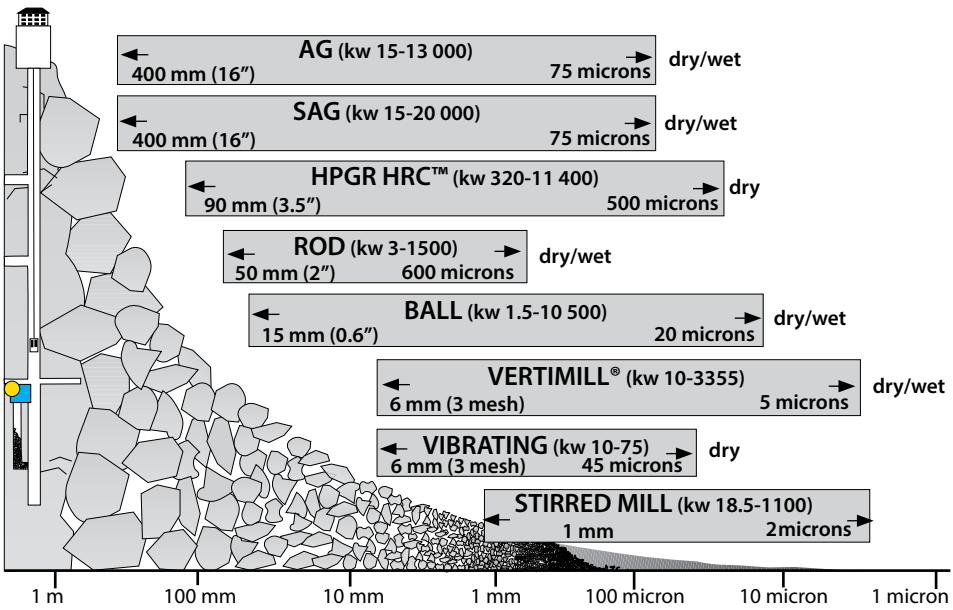
## Grinding methods




## Grinding mills – Reduction ratios

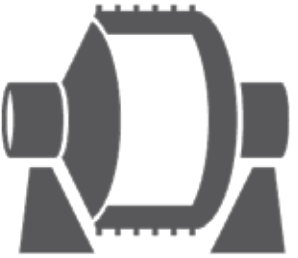
All crushers including impactors have limited reduction ratios. Due to the design there is a restricting in retention time for the material passing.

In grinding as it takes place in more "open" space, the retention time is longer and can easily be adjusted during operation.
Below the theoretical size reduction and power ranges for different grinding mills are shown. In practise also size reduction by grinding is done in optimised stages.



# *Grinding – Tumbling mills*

## *Autogenous (AG) mill*

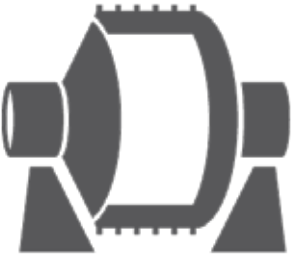


High L/D

Low L/D

- Wet or dry
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed
- High capacity (short retention time)
- Sensitive to feed composition (critical size material), Data sheet 3:44

## *Semi – Autogenous (SAG) mill*



High L/D

Low L/D

- Wet or dry
- Higher capacity than A-G mill grinding
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed plus 4-18% ball charge (ball dia.100-125 mm)
- High capacity (short retention time)
- Less sensitive to feed composition (critical size material), see data sheet 3:44

## *Rod mill*

Overflow

End peripheral discharge

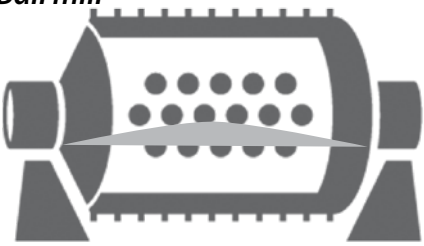
Center peripheral discharge

- Wet only
- Coarse grind
- Primary mill at plant capacities of less than 200t/h
- Coarse grinding with top size control without classification
- Narrow particle size distribution

- Mostly dry
- Coarse grind and high capacity
- Special applications
- End discharge: finer product
- Centre discharge: rapid flow, less fines
- Narrow particle distribution

**Note! No grate discharge**

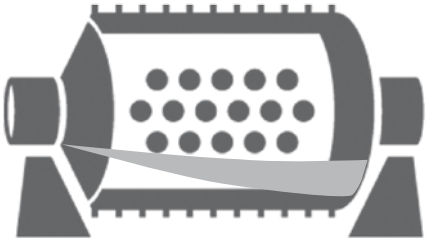
## *Ball mill*



**Overflow**

- Wet only
- Robust and simple
- Mostly in closed circuit (secondary)
- Finer grind (longer retention time)
- Higher risk for over grinding
- Ball charge 35-40%

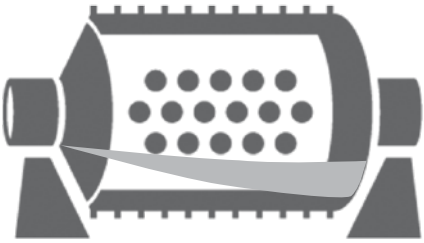
Data sheet, see 3:45



**Grate discharge**

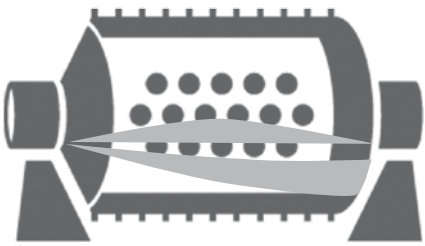
- Dry or wet
- Discharge end more complicated
- Mostly in closed circuit (secondary)
- Coarser grind (shorter retention time)
- Lower risk for over grinding
- Can take about 5-10% more ball with correspondingly higher through put

## *Pebble mill*



- Wet or dry
- Always grate discharge
- Secondary grinding
- Grinding media:
  - A fraction screened out from feed
  - Flint pebbles
  - Porcelain balls
  - $Al_2O_3$ balls
- Larger than ball mills at same power draw
- Grinding without metallic contamination

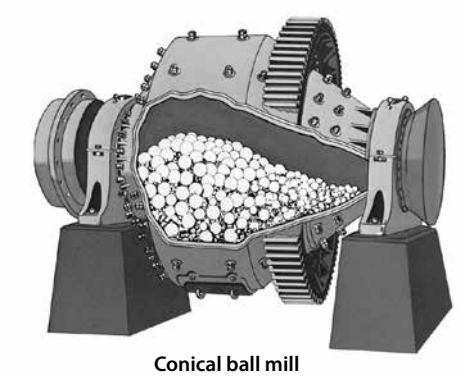
## *Spherical roller antifriction bearing supported mill*



- Wet or dry
- Overflow or grate discharge
- Economic solution
- Simple design type trunnion anti-friction roller bearings and lubrication system
- Smaller capacity
- Reliable technology

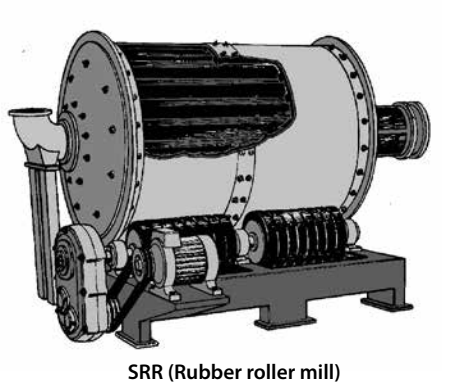
Data sheet, see 3:47

## *Special tumbling mills*



**Conical ball mill**

- Wet or dry (air swept)
- Overflow or partial grate
- Conical shell for "graded" ball charge
  and optimal size reduction
- Only available in small and intermediate sizes
- Efficient "high reduction ratio" grinding
  Data sheet, see 3:48



**SRR (Rubber roller mill)**

- Wet or dry
- Overflow and grate discharge
- Light and fabricated construction
- Ready assembled on steel frame
- Easy to move
- Limited in size (max. dia. 2.4 m)
  Data sheet, see 3:49

# *Grinding – Stirred mills*

## *VERTIMILL®*

- Wet grinding only
- Top or bottom feed
- Grinding by attrition/abrasion
- Primary-, regrinding- or lime slaking mill
- Ideal for "precision" grinding on finer products
- Recommended feed top size of <6 mm
- Equipment sizes from 15 to 4500 HP
  (11 to 3352 kW)
- Ball size max 50mm

## *Comparison with conventional tumbling mills*

- Lower installation cost
- Lower operating costs
- Higher efficiency
- Less floor space
- Simple foundation
- Less noise
- Few moving parts
- Less overgrinding
- Better operation safety

Data sheet, see 3:50 - 52

### *Stirred media grinding mlll*

Wet grinding only

- Open or closed circuit
- Recommended feed size 100 micron and below
- Product size down to 2 micron

Grinding media:

Ceramic or Sand Grinding Media, 1-8 mm in diameter

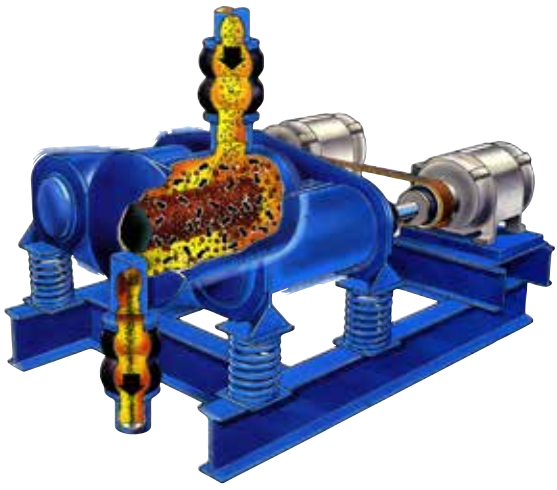
Ceramic media is typically recommended because of lower media consumption,l higher grinding efficiency, and lower wear rates of internal components.

1 Lab Unit, 2 Pilot Units, and 4 full size machines are available (90 kW, 185 kW, 355 kW,and 1100 kW).

Data sheet, see 3:53

## *Grinding – Vibrating mills*

### *Vibrating ball mill*



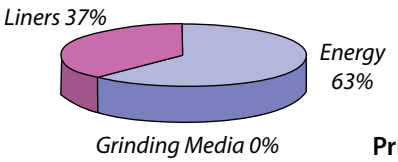
- Wet or dry
- Impact, shearing and attrition
- Open or closed circuit
- Short retention time - less overgrinding
- Feed size, minus 5 mm
- Limited in size
  2x37 kW, 2x50 hp
- High noise level
- Low cost, simple installations
- Low capacity
- Specially applications

Data sheet, see 3:53

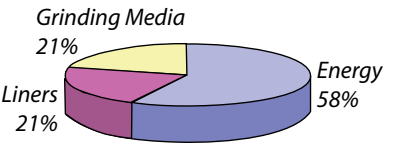
## *Cost of grinding – Typical*

The main costs for grinding are **energy, liners and grinding media**. They are different for different mill types. Below some figures for tumbling mills

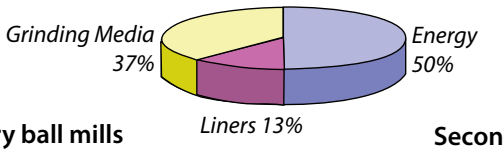
**AG mills**



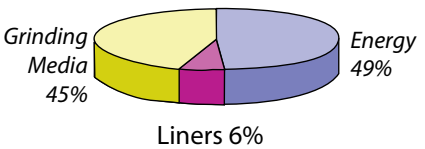

**SAG mills**



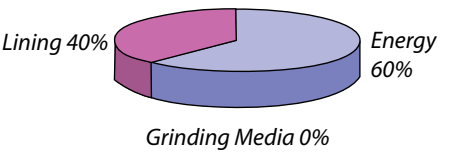

**Primary ball mills**




**Secondary ball mills**




**Secondary pebble mills**




## *Mill linings – Basic*

Use **rubber** linings wherever possible due to lifetime, low weight, easy to install and noise dampening.
When application is getting tougher use **steel-capped rubber**, still easier to handle than steel.

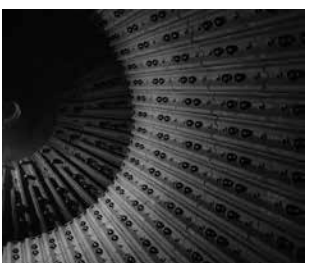
When these both options are overruled (by temperature, feed size or chemicals) use **steel.**
**Ore-bed** is a lining with rubber covered permanent magnets used for special applications like lining of Vertimills, grinding of magnetite a.o, see also Wear in operation, section 9.

### *Lining components*

*Rubber linings*

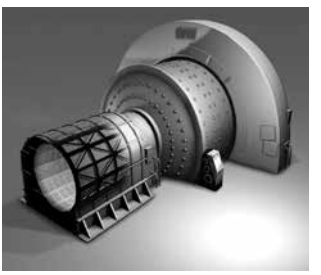
*Poly-Met® linings*

*Metallic linings*



*Orebed® linings*

*Trommel screens*



*Discharge systems*

## Grinding mills – Sizing

Even today this is more of an art than a science. Therefore it should be left to the application offices of your supplier for any valid statements or quotes.

Below will be described some basics of how mills are sized, only.

Fundamental to all mill sizing is determining the necessary specific power consumption for the grinding stage (primary, secondary, tertiary etc.) in question.

It can be established in many ways, some including:

1. Operating data from existing mill circuit (direct proportioning).
2. Grinding tests in pilot scale, where the specific power consumption is determined (kWh/t dry solids).
3. Laboratory tests in small batch mills to determine the specific energy consumption.
4. Energy and power calculations based on Grind Ability Index, for example, Bond work index, (called Wi and normally expressed in **kWh/ short ton**), see 3:40.
5. Population balance modeling and other simulation techniques

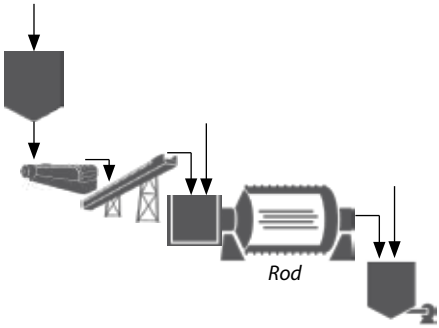
Scale-up criterion is the net specific power consumption, i.e. the power consumed by the mill rotor itself minus all mechanical and electrical losses divided by the feed rate of solids. For the full scale mill this is then to be multiplied by the feed rate to get the net mill power. This must then be increased by the anticipated mechanical inefficiencies (trunnion and pinion bearing friction, ring gear/pinion friction and possible speed reducer losses) as well as electrical losses, in order to arrive at the gross power.

In our labs we can run tests batchwise (in kg scale), or for more critical applications in pilot scale (200-1000 kg/h). The pilot tests are more accurate, but also more expensive.

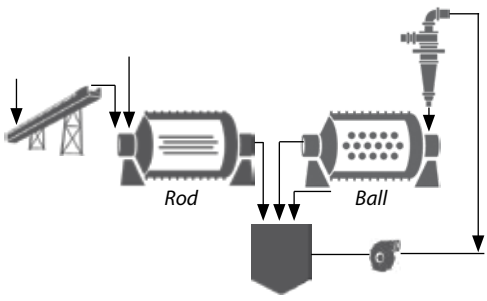
For all AG or SAG installations such tests are mandatory, since they will tell whether this type of grinding is possible at all, as well as establishing the necessary specific power consumption.

## Grinding circuits

Wet grinding of feed $k_{80}$ 25 - 30 mm (1″ - 1 $^{1}/_{4}$″) to product size $k_{80}$ 0.3 mm to 2 mm (8 Mesh - 48 Mesh) in open circuit.

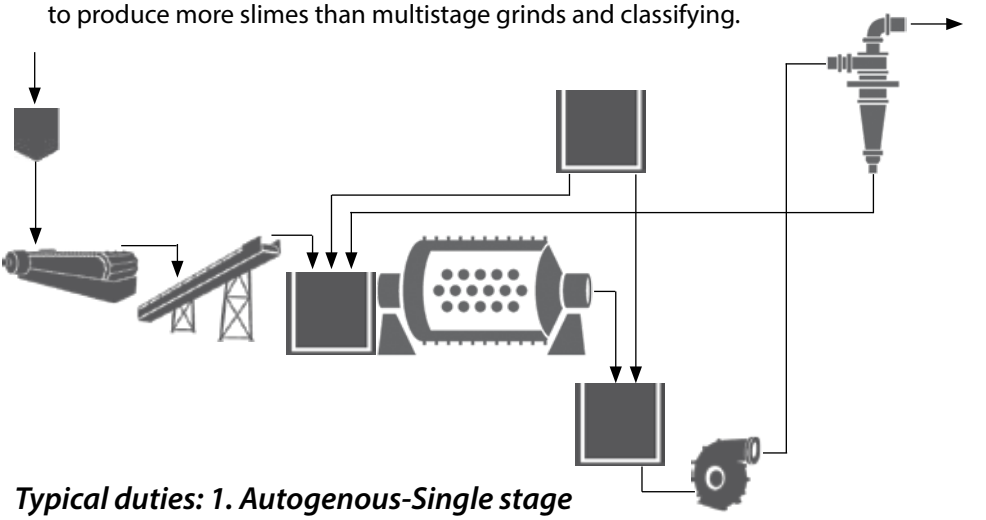



One of the most common flow-sheets for concentrating plants to wet grind - 25 mm (1″) feeds (or finer) to desired product size. Rod mill discharge ab. 1 mm (16 Mesh).



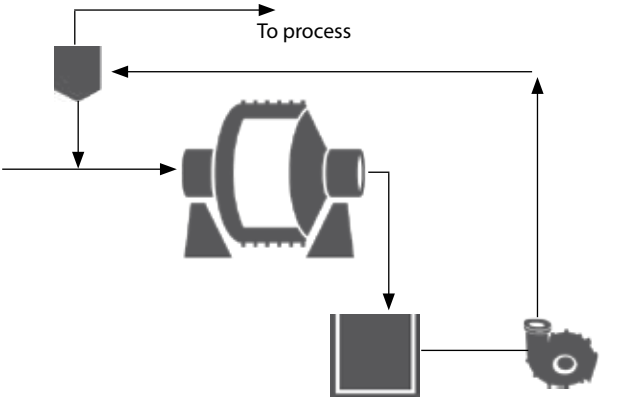
### *Typical duties: (Single stage ball grinding and single classification circuit)*

The most simple and common (although not the most efficient) circuit to wet grind from max. feed sizes of k80 15 mm (5/8") and finer to required product sizes. Tend to produce more slimes than multistage grinds and classifying.



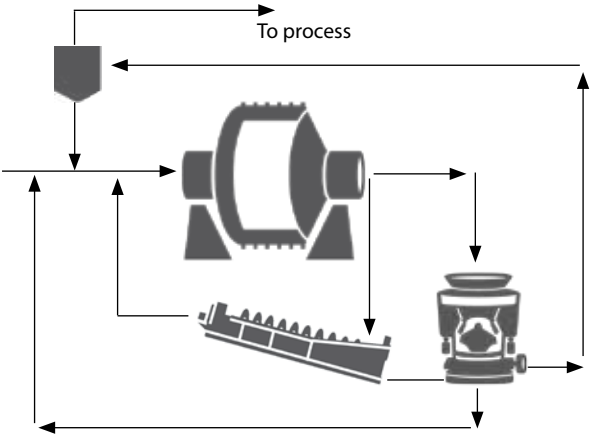
### *Typical duties: 1. Autogenous-Single stage*

For the rare cases where primary AG milling will inherently produce the required product size. (Wet or dry)



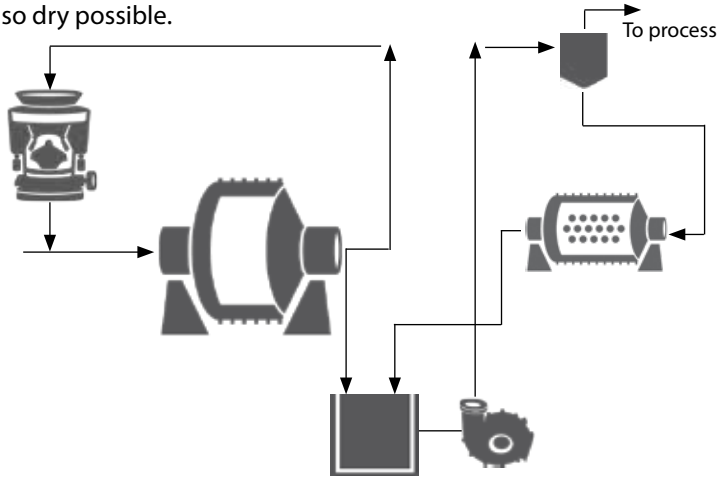

### *Typical duties: 2. Autogenous + Crusher*

For the also not too common cases where critical size pebbles are created and thus inefficient grinding results. With pebble ports in the mill grate and separate crushing of the critical sizes this can be remedied. However, resulting product size must match product requirements. (Wet or dry)



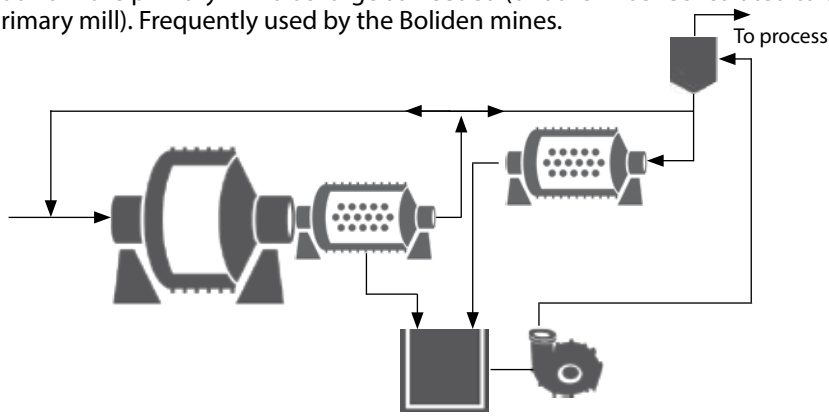
### *Typical duties: 3. Autogenous + Ball mill + Crusher*

This is also called "ABC-circuit" and has a ball mill added in comparision with the above circuit No 2. This can be used to correct a too coarse product from the primary mill, and in this way be more useful and common. Mostly operated wet, but also dry possible.



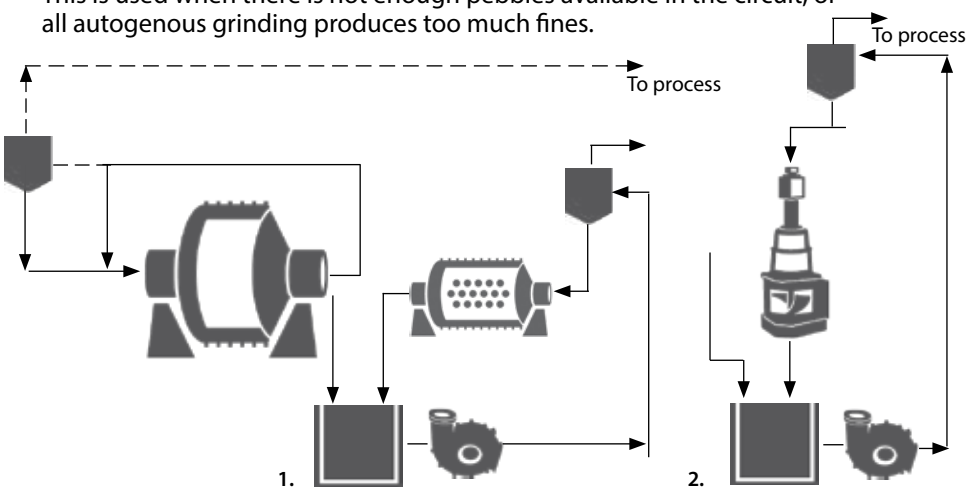

### *Typical duties: 4. Autogenous + Pebble mill*

Two stage AG-grinding with the primary mill in open circuit and the secondary pebble mill in closed circuit. The pebble mill gets competent pebbles screened out from the primary mill discharge as needed (or otherwise recirculated to the primary mill). Frequently used by the Boliden mines.



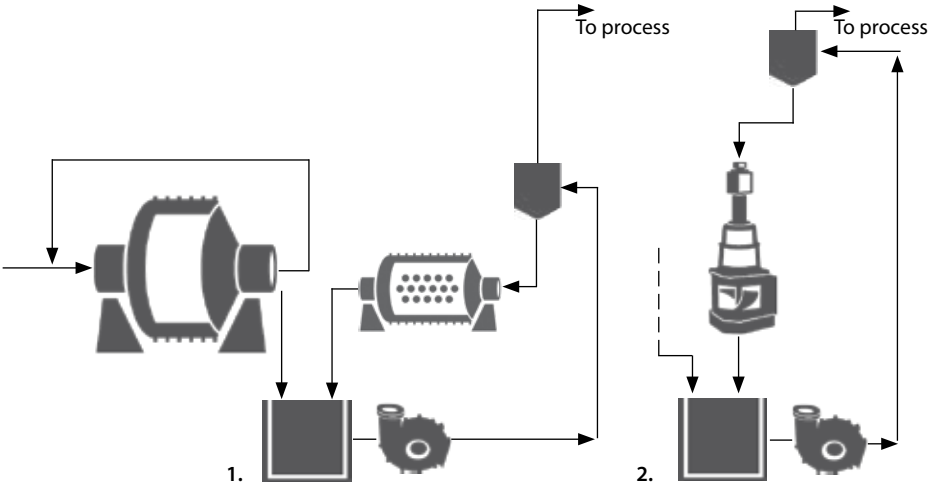

### *Typical duties: 5. Autogenous + Ball mill / VertiMill*

Same as the above, but with the pebble mill replaced by a ball mill or a Vertimill. This is used when there is not enough pebbles available in the circuit, or all autogenous grinding produces too much fines.



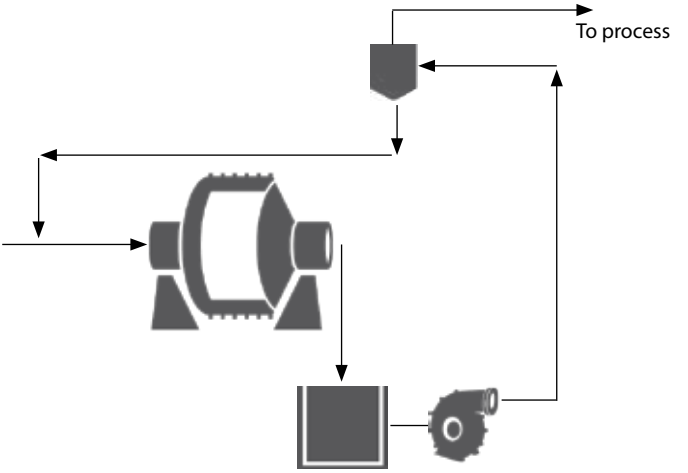
### *Typical duties: 6. Semi-autogenous + Ball mill / VertiMill*

Same as the above No. 5, but with the primary mill as semi-autogenous, which in most cases means higher capacity for the circuit. Many circuits type No. 5 in the US / Canada have been converted to this circuit.



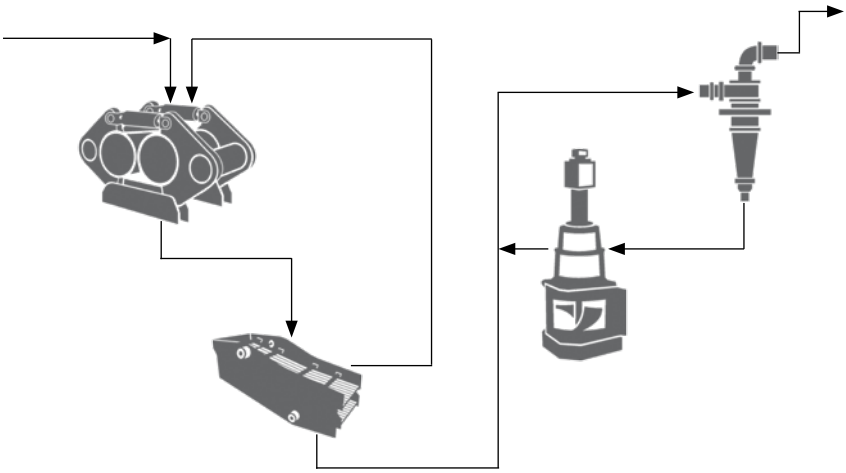

### *Typical duties: 7. Semi-autogenous-Single stage*

Same as No.1 above, but with the mill as semi-autogenous. This will increase capacity as well as application range, but will also increase wear costs (balls and lining) and still be dependent on "natural" product size being close to the desired. Common circuit in the US and Canada.



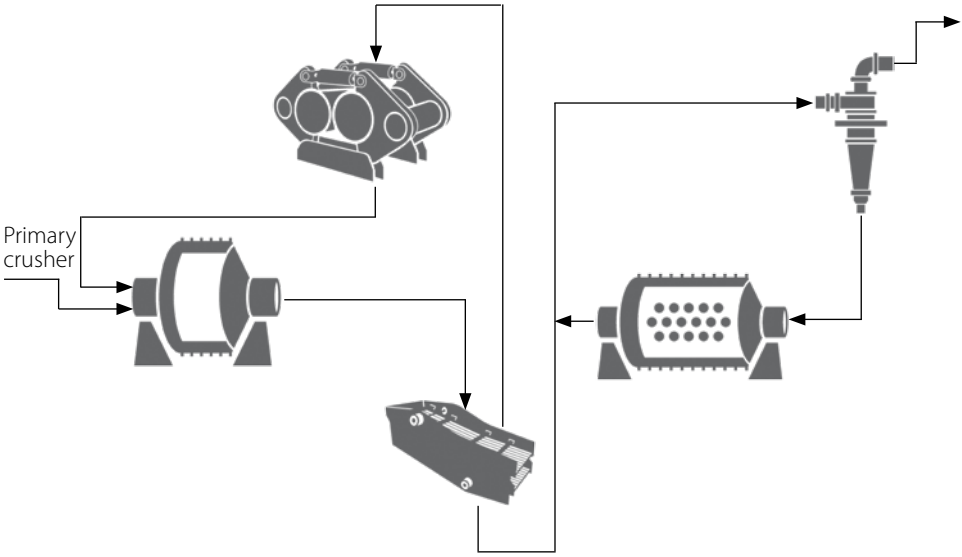
### *Typical duties: 8. HRC™ + Vertimill®*

In this circuit, the cone crusher product is fed to the HRC™ which produces the required reduction for enrichment with the Vertimill processing the regrind. When applicable, this type of circuit can offer significant energy savings.



### *Typical duties: 9. AG mill + HRC™ + Ball mill*

In this circuit, the AG mill is followed by a single deck screen with the oversize being recirculated through the HRC™ before returning to the AG mill. The undersize from the screen is fed to the ball mill circuit sump. The AG mill can be replaced by a SAG Mill, however special care should be used to detect and remove balls from the HRC™ feed.



# *VERTIMILL® Circuits*



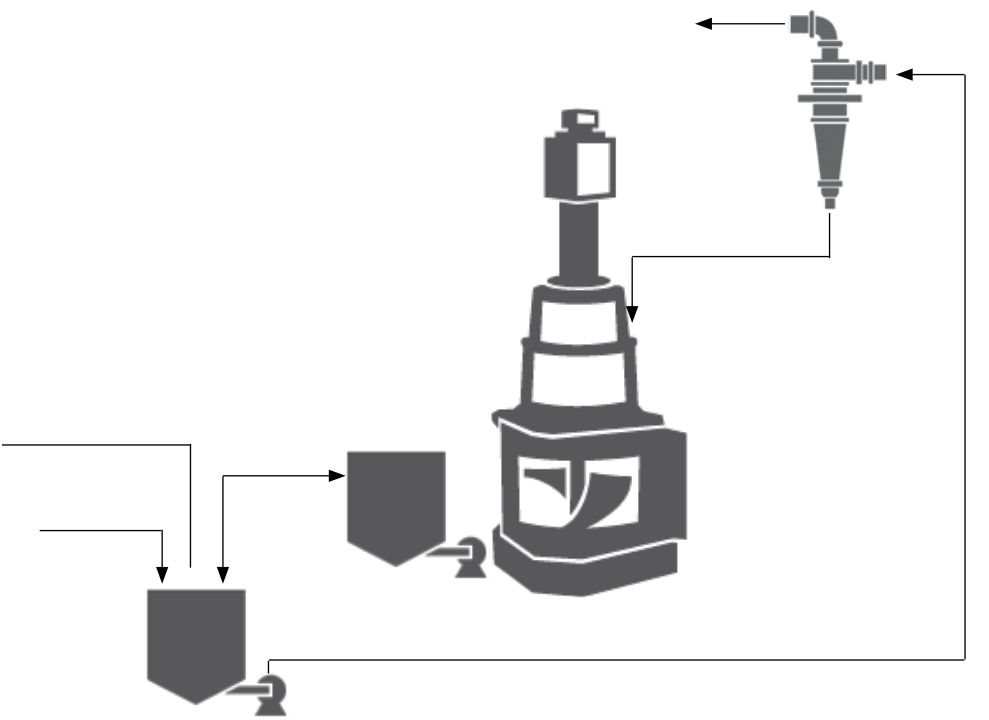
## *Typical duties: 10. Reversed closed circuit*

**Scalped or fresh feed directly into the mill**

If it is desirable to use cyclones, the next decision is where in the process the cyclones should be – either closed circuit or reversed closed circuit. Typical closed circuit has the feed to the Vertimill circuit coming directly to the mill. This means that every particle regardless of size will enter the mill and may be ground. For reverse close circuit, the feed to the Vertimill circuit is introduced at the cyclone sump. The material feeding the circuit that is already at product size will have a chance to bypass the Vertimill all together, and the grinding energy will only be spent on the coarse material. This can reduce the size (and capital cost) of the Vertimill installation.

Mineralogically, there may be some benefit to direct feed in that flotation recovery may improve if all the particles surfaces, regardless of the particle size, are polished or refreshed. The reversed arrangement will minimize fines generation, which may also improve recovery. To best make a mineralogical decision, you need to have a good understand on where the losses are in the flotation circuit.

From a circuit energy perspective, in general, if the feed has very little material (<10%) that is final product size, it is better to feed it directly to the mill because the cyclone or other classifying device will send it all back to the Vertimill anyway and you would be putting undue load on the cyclone feed pumps. If there is a fair amount of fines and the classification is reasonable efficient, pre-classifying the material is beneficial.



## *Typical duties: 11. Direct feed*

**Circuit Configuration**

In addition to cyclones or other external classification, there are four ways to configure a Vertimill circuit:

- Top feed with recycle system
- Top feed without recycle system
- Bottom feed with recycle system
- Bottom feed without recycle system

Bottom and top feeding configuration advantages and disadvantages are listed below and are exclusive of the use separating tank and recycle system:

**Bottom feed advantages**

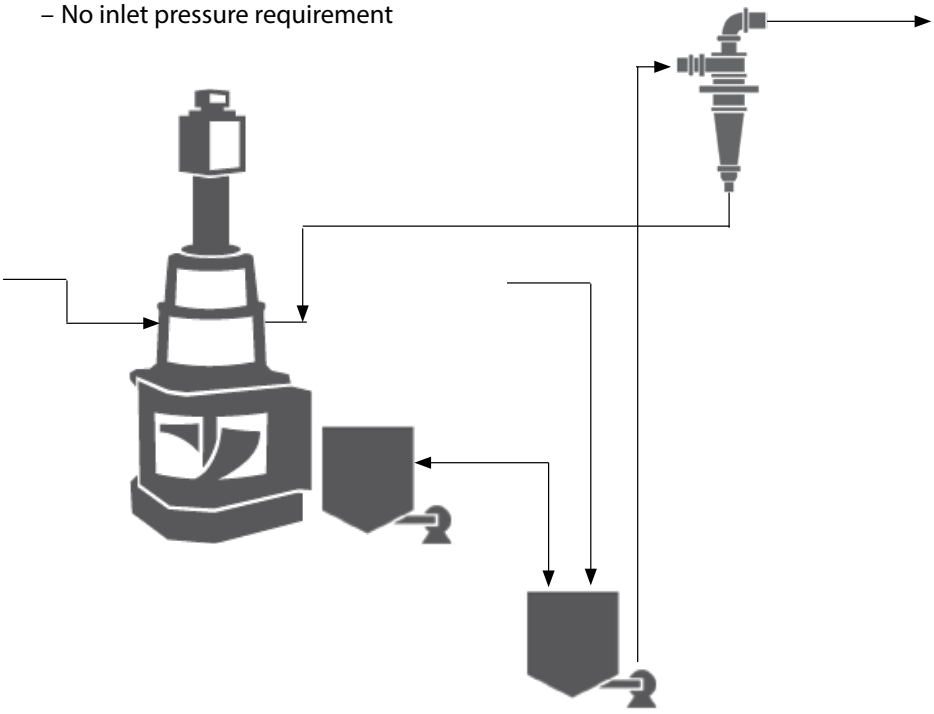
– All Particles must pass through the media, every particle surface is refreshed
– Provides additional upward classifying flow
– Can help free locked or frozen charge at start up
– Potentially more efficient because of lack of short circuiting
– Fine particles must pass through the media – potential for over grinding

**Bottom feed disadvantages**

– Can be bottom fed via gravity or pump
– Back flow
  – need no return valves or a tall tank
  – Piping must loop above ball charge height so ball to not get to the pump
– Requires variable speed pumps
– Tank requires flow split and level control
– Minimum inlet pressure requirement to prevent plugging

**Top feed advantages**

– Does not require a feed pump; can be feed directly from cyclones
– No inlet pressure requirement



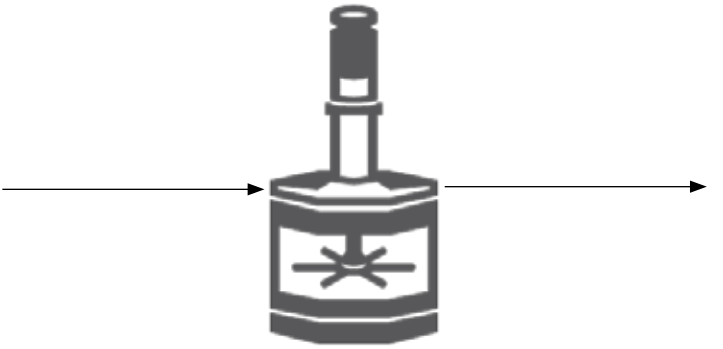
# *Stirred Media Detritors (SMD) Circuits*



## *Typical duties: 12. Open circuit, whole feed*

SMDs already utilize inert grinding media to improve flotation recovery, but the surface preparation of the particle may also be important for the flotation response.
The whole stream can be fed direct to the mills in open circuit so that all of the material gets some grinding to prepare the surface for flotation.

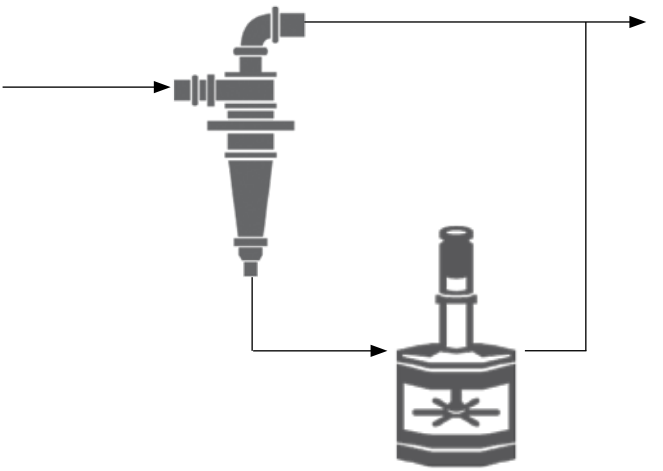
If the upstream process can provide steady feed rate and solids concentration (i.e. a thickener), the SMD can be operated in open circuit with no additional equipment required. If the feed rate or solids concentration will fluctuate periodically, then including a buffer tank to feed the mills is advised.



## *Typical duties: 13. Open circuit, scalped feed*

If the losses in the flotation circuit are in the coarse, un-liberated material and fines generation needs to be minimized, then the SMD will be most efficient at increasing the recovery by grinding just the coarse material. Scalping cyclones can be used ahead of the mill to scalp the fines and send them straight to the next process, and the cyclone under flow feeds the SMD, and is then recombined with the cyclone overflow for the next process.

As previously stated, the SMD is best operated between 40-50% solids, and a scalping cyclone also provides a nice solution to thicken the feed to the mill.

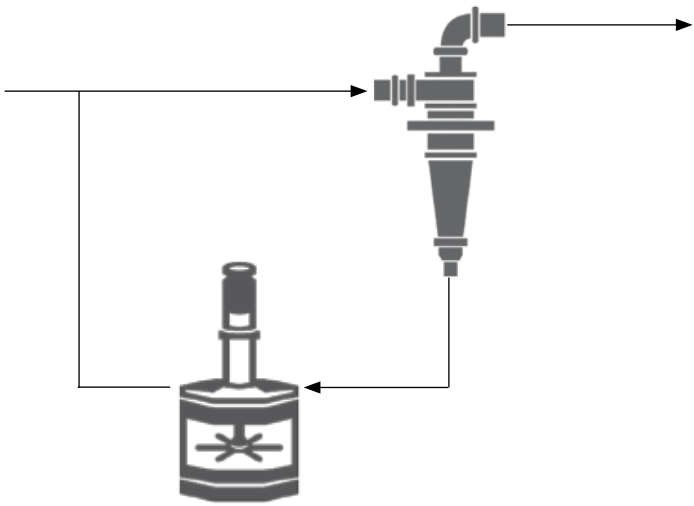


### *Typical duties: 14. Closed circuit*

The SMD can also be operated in closed circuit. This arrangement provides all the advantages of the Open Circuit, Scalped feed configuration, but also provides a method to control the particle size other than feed rate and mill power..

The SMD operates quite well in an open circuit configurations, and only a handful are operated in closed circuit. For ultrafine grinding, operating in closed circuit is difficult because the small diameter cyclone can easily plug. Closed circuit configuration is primarily used in coarser grinding applications and when the specific energy is low - the average residence time of the particle is short.





## Grinding – Power calculation

The most common formula for this is the Bond* formula

W (specific power consumption) = 10 x Wi ( $\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}}$)

with P and F the 80% passing sizes of product and feed in microns and Wi expressed as kWh/sh.t.

Then for P = 100 and F very large, Wi is roughly the same as W, or in other words equal to the specific power consumption to comminute a material from infinite size to $k_{80}$ = 100 microns see below.

* Fred Bond, Allis Chalmers Corp.



## Grinding – Bonds Work Index*

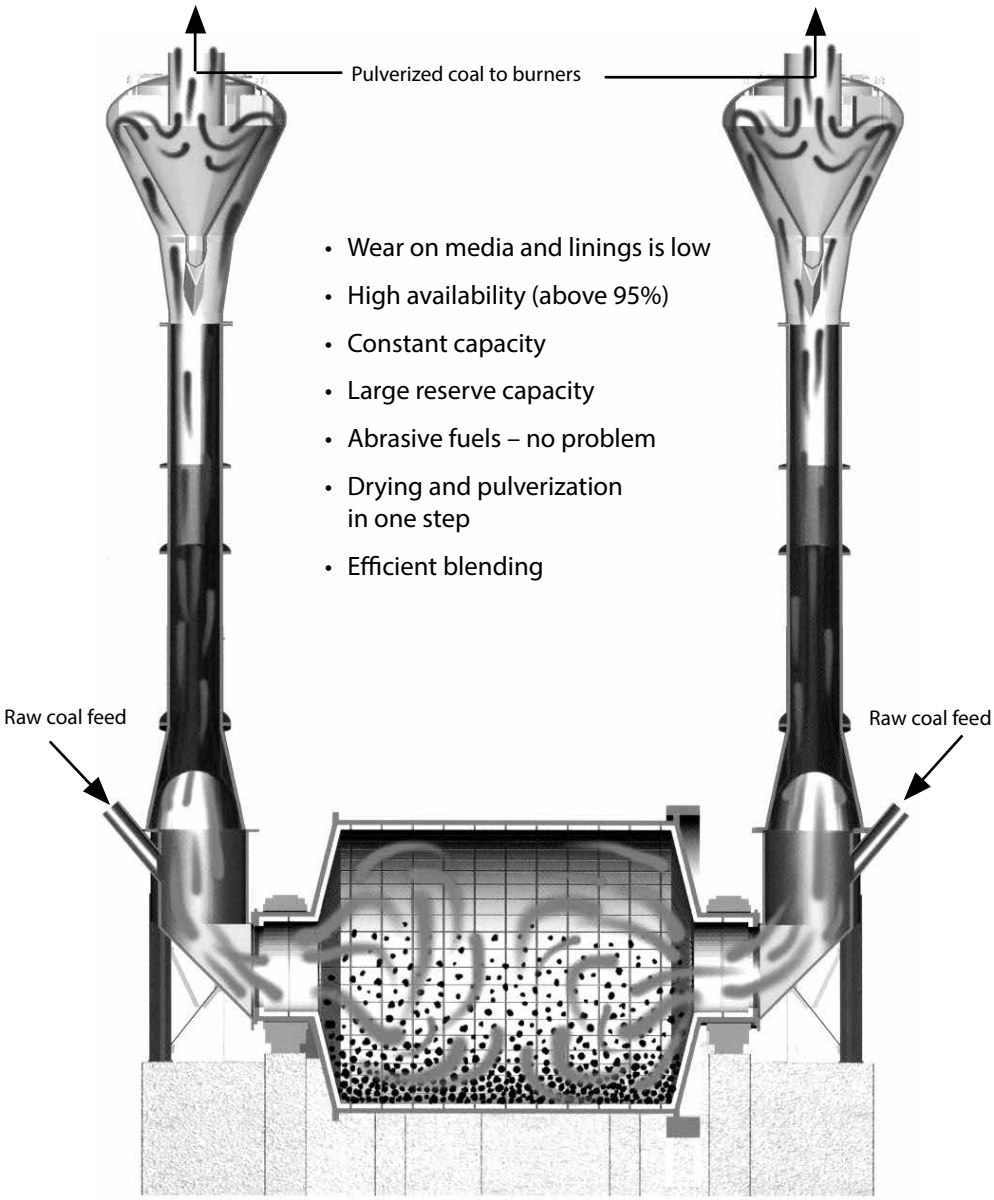
| Solids [kWh/sh.ton] | Wi |
|---|---|
| Andesite | 18.25 |
| Barite | 4.73 |
| Basalt | 17.10 |
| Bauxite | 8.78 |
| Cement clinker | 13.45 |
| Cement raw material | 10.51 |
| Clay | 6.30 |
| Coal | 13.00 |
| Coke | 15.13 |
| Copper ore | 12.72 |
| Diorite | 20.90 |
| Dolomite | 11.27 |
| Emery | 56.70 |
| Feldspar | 10.80 |
| Ferro-chrome | 7.64 |
| Ferro-manganese | 8.30 |
| Ferro-silicon | 10.01 |
| Flint | 26.16 |
| Fluorspar | 8.91 |
| Gabbro | 18.45 |
| Glass | 12.31 |
| Gneiss | 20.13 |
| Gold ore | 14.93 |
| Granite | 15.13 |
| Graphite | 43.56 |
| Gravel | 16.06 |
| Gypsum rock | 6.73 |
| Hematite | 12.84 |

| Solids [kWh/sh.ton] | Wi |
|---|---|
| Magnetite | 9.97 |
| Taconite | 14.61 |
| Lead ore | 11.90 |
| Lead-zinc ore | 10.93 |
| Limestone | 12.74 |
| Manganese ore | 12.20 |
| Magnesite | 11.13 |
| Molybdenum | 12.80 |
| Nickel ore | 13.65 |
| Oil shale | 15.84 |
| Phosphate rock | 9.92 |
| Potash ore | 8.05 |
| Pyrite ore | 8.93 |
| Pyrrhotite ore | 9.57 |
| Quartzite | 9.58 |
| Quartz | 13.57 |
| Rutile ore | 12.68 |
| Shale | 15.87 |
| Silica sand | 14.10 |
| Silicon carbide | 25.87 |
| Slag | 10.24 |
| Slate | 14.30 |
| Sodium silicate | 13.40 |
| Spodumene ore | 10.37 |
| Syenite | 13.13 |
| Tin ore | 10.90 |
| Titanium ore | 12.33 |
| Trap rock | 19.32 |
| Zinc ore | 11.56 |

**These values are not constant and must be used accordingly!*

## *Pulverizing of coal*

Coal pulverizing is an important application for grinding mills (ball mill type) and the advantages of using tumbling grinding are many.


Pulverized coal to burners
• Wear on media and linings is low
• High availability (above 95%)
• Constant capacity
• Large reserve capacity
• Abrasive fuels – no problem
• Drying and pulverization in one step
• Efficient blending
Raw coal feed
Raw coal feed

Double ended, air-swept ball mill system

### *Typical capacities (feed moisture 8%)*

| Mill size m | ft | Coal flow (mtph) | Motor power kW/hp |
|---|---|---|---|
| 3.8x5.8 | 12.5x19 | 42 | 820/1 100 |
| 4.0x6.1 | 13x20 | 50 | 969/1 300 |
| 4.3x6.4 | 14x21 | 62 | 1193/1 600 |
| 4.7x7.0 | 15.5x23 | 82 | 1640/2 200 |
| 5.0x7.7 | 16.5x25 | 110 | 2237/3 000 |
| 5.5x8.2 | 18x27 | 141 | 2760/3 700 |

## *VERTIMILL® – More than a grinding mill*

The VERTIMILL® grinding mill is considered to be an "intelligent" grinding concept giving an energy saving and controlled process of size reduction. For comparison with tumbling mills, see 3:26.

### *Mineral applications*

- Fine / Ultra fine grinding
- Primary grinding
- Secondary grinding
- Tertiary grinding
- "In circuit" regrinding of concentrates

### *FGD applications*

- Fine grinding of lime stone
- Lime slaking, see next page

### *Fuel preparation*

- Clean coal
- Coal / water
- Coal / oil

## *VERTIMILL® as lime slaker*

The VERTIMILL® is an excellent lime slaker producing an optimal product in a simple one-step operation.

### *Typical operation conditions:*

| | |
|---|---|
| **Material** | Pebble lime with approximately 5 % grit |
| **Feed size** | minus 25mm (1") |
| **Product size** | 80% passing 75 microns to 90-95% passing 45 microns |
| **Percent solids (product)** | 20-26% |
| **Temperature inside mill (product)** | 50-82 °C (130-180°F) |



**Capacities vs mill sizes**

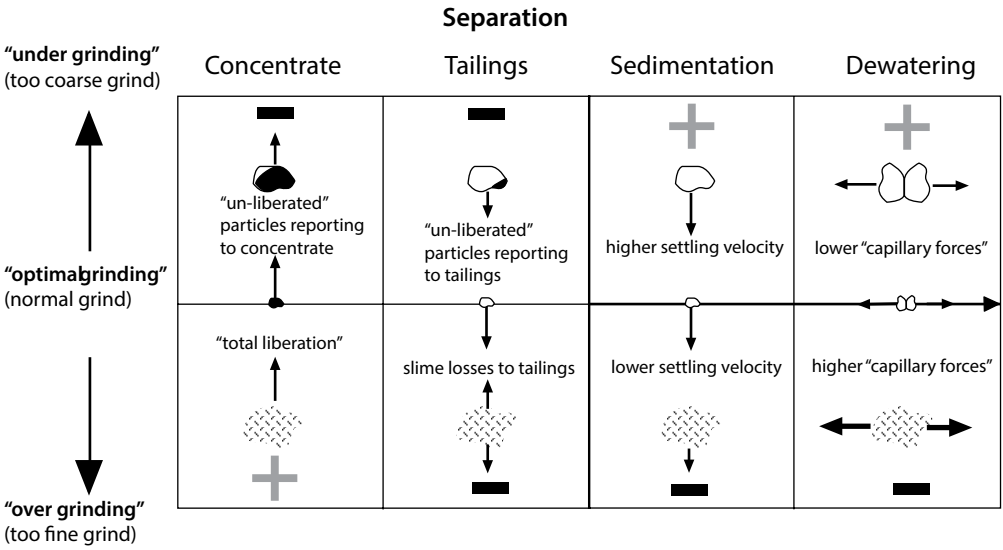
| Mtph CaO | Stph CaO | Mill unit | Motor kW | Motorhp |
|---|---|---|---|---|
| 1.4 | 1.5 | VTM-10-LS | 7.5 | 10 |
| 2.7 | 3.0 | VTM-20-LS | 14.9 | 20 |
| 3.7 | 4.1 | VTM-30-LS | 22.4 | 30 |
| 5.3 | 5.8 | VTM-50-LS | 37.3 | 50 |
| 6.6 | 7.3 | VTM-100-LS | 44.7 | 60 |
| 12.0 | 13.2 | VTM-150-LS | 74.6 | 100 |
| 13.9 | 15.3 | VTM-200-LS | 111.9 | 150 |
| 18.7 | 20.6 | VTM-300-LS | 149.1 | 200 |
| 30.0 | 33.0 | VTM-400-LS | 223.7 | 300 |

## *Grinding vs enrichment and upgrading*

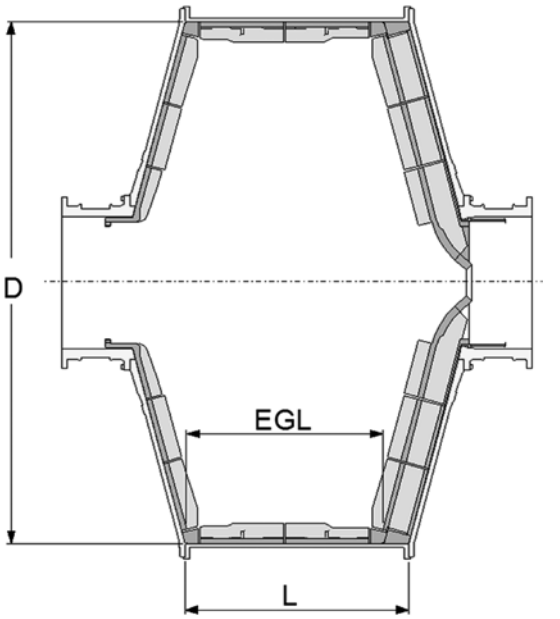
In the size reduction stages of grinding we are also creating the conditions for the following process stages of enrichment and upgrading.

From the picture below we can see the effect of "under- and over grinding".

The lost performance in separation, sedimentation and dewatering due to "mis-grinding" represents a major problem for many operations, eroding the process economy.

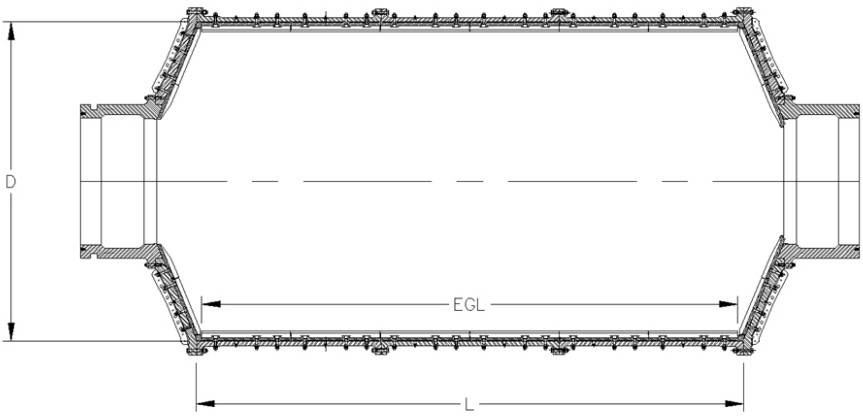


## *AG and SAG mills*




| Standard Mill size (m) | EGL (m) | Geared/Gearless | Std %TCS | Motor hp/kW (Typical) |
|---|---|---|---|---|
| 12′ x 5′ (3,7 x 1,5) | 4′ (1,2) | Geared | 75 | 150-250/110-185 |
| 14′ x 6′ (4,2 x 1,8) | 5′ (1,5) | Geared | 75 | 300-500/220-370 |
| 16′ x 7′ (4,8 x 2,1) | 6′ (1,8) | Geared | 75 | 550-850/400-630 |
| 18′ x 8′ (5,5 x 2,4) | 6.75′ (2,0) | Geared | 75 | 900-1300/670-970 |
| 20′ x 8′ (6,0 x 2,4) | 6.75′ (2,0) | Geared | 75 | 1000-1750/745-1300 |
| 21′ x 10′ (6,4 x 3,0) | 8.75′ (2,7) | Geared | 75 | 1600-2500/1200-1860 |
| 22′ x 10′ (6,7 x 3,0) | 8.75′ (2,7) | Geared | 75 | 2000-3000/1490-2240 |
| 24′ x 10′ (7,3 x 3,0) | 8.75′ (2,7) | Geared | 75 | 2500-3500/1860-2610 |
| 26′ x 10′ (7,9 x 3,0) | 8.75′ (2,7) | Geared | 75 | 3000-4500/2240-3350 |
| 28′ x 10′ (8,5 x 3,0) | 8.5′ (2,6) | Geared | 75 | 3500-5500/2610-4100 |
| 28′ x 14′ (8,5 x 4,3) | 12.5′ (3,8) | Geared | 75 | 5000-8000/3730-5960 |
| 30′ x 12′ (9,1 x 3,7) | 10.5′ (3,2) | Geared | 75 | 5000-8000/3730-5960 |
| 32′ x 14′ (9,8 x 4,3) | 12.5′ (3,8) | Geared | 75 | 7-11000/5-8200 |
| 32′ x 16′ (9,8 x 4,8) | 14.5′ (4,4) | Geared | 75 | 8-12000/6-8950 |
| 34′ x 15′ (10,3 x 4,6) | 13.25′ (4,0) | Geared | 75 | 8-13000/6-9700 |
| 34′ x 17′ (10,3 x 5,2) | 15.25′ (4,6) | Geared | 75 | 10-15000/7-11190 |
| 34′ x 19′ (10,3 x 5,8) | 17.25′ (5,3) | Geared | 75 | 11-17000/8-12680 |
| 36′ x 15′ (11,0 x 4,6) | 13.25′ (4,0) | Geared/Gearless | Variable | 10-16000/7-11930 |
| 36′ x 17′ (11,0 x 5,2) | 15.25′ (4,6) | Geared/Gearless | Variable | 11-18000/8-13420 |
| 36′ x 19′ (11,0 x 5,8) | 17.25′ (5,3) | Geared/Gearless | Variable | 12-20000/9-14900 |
| 38′ x 20′ (11,6 x 6,0) | 18′ (5,5) | Geared/Gearless | Variable | 15-24000/11-17800 |
| 40′ x 22′ (12,0 x 6,7) | 19.5′-20′ (5,9-6,1) | Gearless | Variable | 19-30000/14-22370 |
| 42′ x 25′ (12,8 x 7,6) | 22.5′ (6,8) | Gearless | Variable | 23-36000/17-26850 |

# *Ball mills*



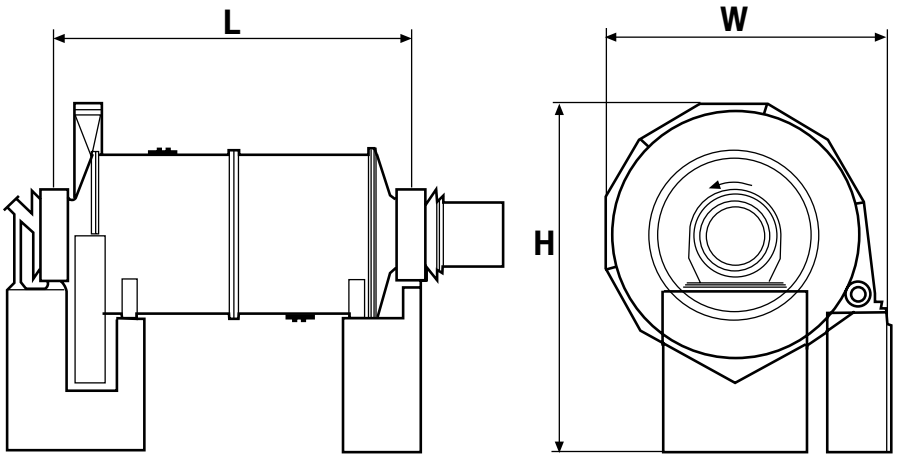



| Standard Mill size (m) | Geared/Gearless | Std %TCS | Approx hp/kW | Motor hp/kW |
|---|---|---|---|---|
| 9′ x 12′ (2,7x3,7) | Geared | 76 | 388/290 | 450/335 |
| 9′ x 14′ (2,7x4,2) | Geared | 76 | 455/340 | 500/373 |
| 9.5′ x 15′ (2,9x4,6) | Geared | 76 | 564/420 | 600/447 |
| 10′ x 15′ (3,0x4,6) | Geared | 76 | 596/445 | 700/522 |
| 10.5′ x 15′ (3,2x4,6) | Geared | 76 | 734/547 | 800/597 |
| 10.5′ x 17′ (3,2x5,2) | Geared | 76 | 836/623 | 900/671 |
| 11′ x 17′ (3,3x5,2) | Geared | 76 | 944/704 | 1000/746 |
| 11.5′ x 18′ (3,5x5,5) | Geared | 76 | 1125/839 | 1250/932 |
| 13′ x 17′ (3,9x5,2) | Geared | 76 | 1460/1089 | 1500/1119 |
| 13′ x 19′ (3,9x5,8) | Geared | 76 | 1637/1220 | 1750/1305 |
| 14′ x 18′ (4,2x5,5) | Geared | 76 | 1877/1400 | 2000/1491 |
| 14′ x 20′ (4,2x6,0) | Geared | 76 | 2091/1559 | 2250/1677 |
| 15′ x 19′ (4,6x5,8) | Geared | 76 | 2372/1769 | 2500/1864 |
| 15.5′ x 21′ (4,7x6,4) | Geared | 76 | 2861/2133 | 3000/2237 |
| 16.5′ x 21′ (5,0x6,4) | Geared | 76 | 3362/2507 | 3000/2237 |
| 16.5′ x 24′ (5,0x7,3) | Geared | 76 | 3854/2873 | 4000/2983 |
| 16.5′ x 27′ (5,0x8,2) | Geared | 76 | 4346/3240 | 4500/3356 |
| 16.5′ x 30′ (5,0x9,1) | Geared | 76 | 4838/3608 | 5000/3728 |
| 16.5′ x 33′ (5,0x10,0) | Geared | 76 | 5330/3975 | 5500/4101 |
| 18′ x 29′ (5,5x8,8) | Geared | 76 | 5847/4360 | 6000/4474 |
| 18′ x 31.5′ (5,5x9,6) | Geared | 76 | 6360/4743 | 6000/4474 |
| 18′ x 33.5′ (5,5x10,2) | Geared | 76 | 6771/5049 | 7000/5220 |

Continues on next page.

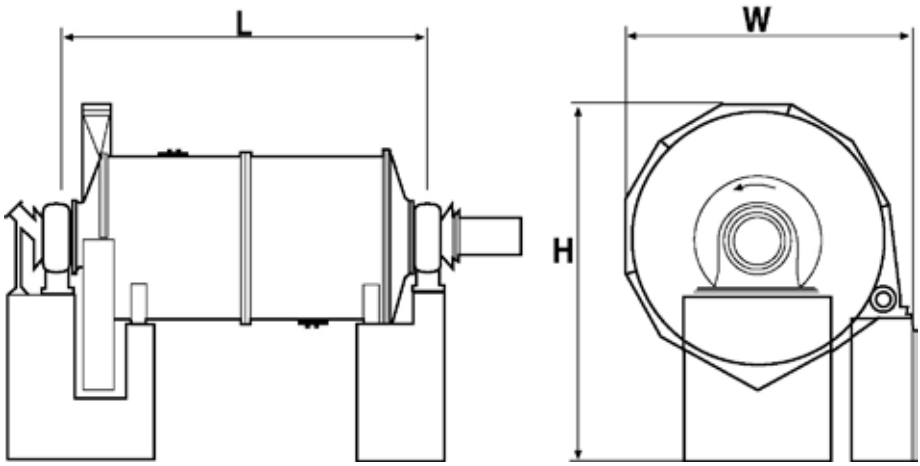
## *Ball mills (continue)*





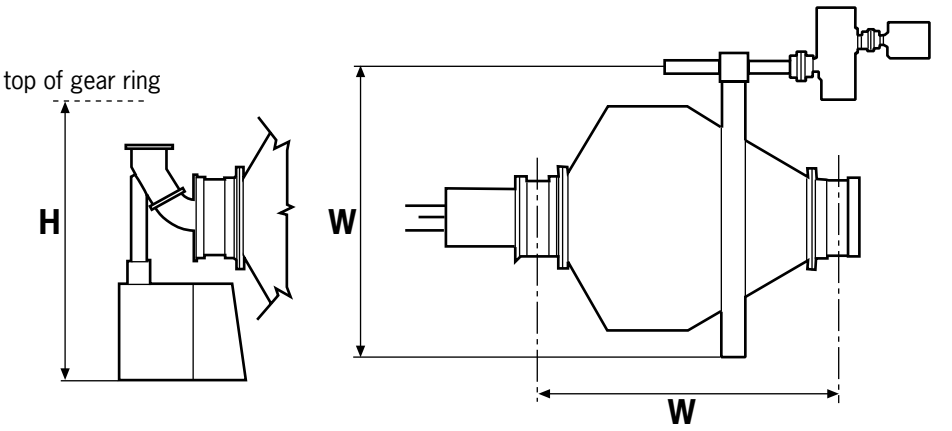

| Standard Mill size (m) | Geared/Gearless | Std %TCS | Approx hp/kW | Motor hp/kW |
|---|---|---|---|---|
| 20′ x 31.5′ (6x9,6) | Geared | 76 | 8336/6212 | 8000/5966 |
| 20′ x 33.5′ (6x10,2) | Geared | 76 | 8874/6617 | 9000/6711 |
| 21′ x 31.5′ (6,4x9,6) | Geared | 76 | 9446/7044 | 10000/7457 |
| 21′ x 33.5′ (6,4x10,2) | Geared | 76 | 10361/7726 | 11000/8203 |
| 22′ x 36.5′ (6,7x11,1) | Geared | 76 | 12357/9215 | 13000/9694 |
| 22′ x 40.5′ (6,7x12,3) | Geared | 76 | 13370/9970 | 14500/10813 |
| 24′ x 36′ (7,3x11) | Geared | 76 | 15220/11350 | 16000/11931 |
| 24′ x 40′ (7,3x12,3) | Geared | 76 | 16935/12628 | 17800/13273 |
| 26′ x 38′ (7,9x11,6) | Geared/Gearless | 76 | 19720/14705 | 20700/15436 |
| 26′ x 40′ (7,9x12,3) | Geared/Gearless | 76 | 20771/15489 | 21800/16256 |
| 26′ x 42′ (7,9x12,8) | Geared/Gearless | 76 | 21823/16273 | 23000/17151 |
| 26′ x 44′ (7,9x13,4) | Geared/Gearless | 76 | 22875/17058 | 24000/17897 |
| 27′ x 45′ (8,2x13,7) | Gearless | 76 | 25763/19211 | 27000/20134 |
| 28′ x 46′ (8,5x14) | Gearless | 76 | 28898/21549 | 30000/22371 |
| 29′ x 47′ (8,8x14,3) | Gearless | 76 | 32291/24079 | 34000/25354 |
| 30′ x 46′ (9,1x14) | Gearless | 76 | 34442/25683 | 36000/26845 |

## *Spherical roller bearing supported ball mill*



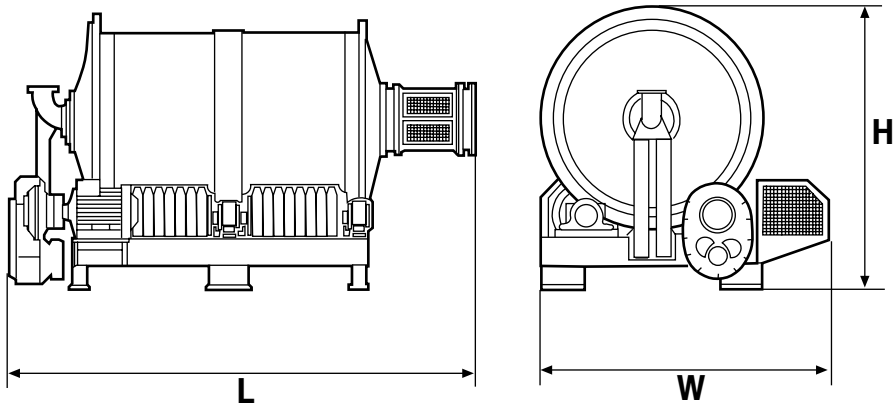

| Mill size m (ft) DxL | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/HP |
|---|---|---|---|---|
| 2.4x3.6 (8x11.8) | 4350 (171) | 5043 (199) | 4650 (183) | 232/311 |
| 2.4x4.2 (8x13.8) | 4350 (171) | 5643 (222) | 4650 (183) | 269/361 |
| 2.4x4.8 (8x15.7) | 4350 (171) | 6243 (246) | 4650 (183) | 306/410 |
| 2.8x4.2 (9x13.8) | 4800 (189) | 5874 (231) | 5700 (225) | 410/550 |
| 2.8x4.9 (9x16) | 4800 (189) | 6574 (259) | 5700 (225) | 474/636 |
| 2.8x5.6 (9x18.4) | 4800 (189) | 7274 (286) | 5700 (225) | 539/723 |
| 3.2x4.8 (10.5x15.7) | 5200 (205) | 6705 (264) | 6790 (267) | 643/863 |
| 3.2x5.6 (10.5x18.4) | 5200 (205) | 7505 (296) | 6790 (267) | 745/1000 |
| 3.2x6.4 (10.5x21) | 5200 (205) | 8317 (327) | 6790 (267) | 846/1135 |
| 3.6x5.4 (11.8x17.7) | 5600 (221) | 7548 (297) | 7140 (281) | 990/1327 |
| 3.6x6.3 (11.8x20.7) | 5600 (221) | 8448 (333) | 7140 (281) | 1145/1535 |
| 3.6x7.2 (11.8x23.6) | 5600 (221) | 9394 (370) | 7140 (281) | 1300/1743 |
| 4.0x6.0 (13x19.7) | 7900 (311) | 8425 (332) | 9000 (355) | 1452/1947 |
| 4.0x7.0 (13x23) | 7900 (311) | 9938 (391) | 9000 (355) | 1679/2251 |
| 4.0x8.0 (13x26) | 7900 (311) | 10425 (410) | 9000 (355) | 1905/2555 |
| 4.4x6.6 (14.4x21.7) | 8000 (315) | 9256 (364) | 9500 (374) | 2054/2754 |
| 4.4x7.2 (14.4x23.6) | 8000 (315) | 9856 (388) | 9500 (374) | 2229/2989 |
| 4.4x7.7 (14.4x25.3) | 8000 (315) | 10356 (408) | 9500 (374) | 2374/3184 |
| 4.4x8.2 (14.4x27) | 8000 (315) | 10856 (427) | 5 700 ( 224) | 2519/3379 |

## *Conical ball mill*




| Mill size m (ft) DxL | H) mm (inch | L mm (inch | W mm (inch | Power motor kW/Hp |
|---|---|---|---|---|
| 2.4x0.9 (8x3) | 3 350 (132) | 3 430 (135) | 3 200 (126) | 112/150 |
| 2.4x1.2 (8x4) | 3 350 (132) | 3 730 (147) | 3 200 (126) | 130/175 |
| 2.4x1.5 (8x5) | 3 350 (132) | 4 040 (159) | 3 200 (126) | 150/200 |
| 2.4x1.8 (8x6) | 3 350 (132) | 4 340 (171) | 3 200 (126) | 186/250 |
| 2.7x1.5 (9x5) | 3 960 (156) | 4 270 (168) | 3 660 (144) | 224/300 |
| 3.0x1.2 (10x4) | 4 360 (168) | 3 810 (150) | 3 660 (144) | 260/350 |
| 3.0x 1.7 (10x5.5) | 4 360 (168) | 4 110 (162) | 3 860 (152) | 300/400 |
| 3.0x1.8 (10x6) | 4 360 (168) | 4 420 (174) | 3 860 (152) | 336/450 |
| 3.0x2.1 (10x7) | 4 360 (168) | 4 720 (186) | 3 860 (152) | 373/500 |

## *SRR mill*






| SRR Ball mill<br>Mill size m (ft)<br>DxL | H<br>mm (inch) | L<br>mm (inch) | W<br>mm (inch) | Power motor<br>kW/Hp | Weight (empty)<br>ton |
|---|---|---|---|---|---|
| 0.6x0.9 (2x3) | 1 110 (44) | 1 830 (72) | 1 220 (48) | 2.2/3 | 0.9 |
| 1.0x1.5 (3.3x5) | 1 635 (64) | 2 700 (106) | 1 850 (73) | 11/15 | 2.4 |
| 1.2x2.4 (4x8) | 1 970 (78) | 3 670 (144) | 2 740 (108) | 30/40 | 5.6 |
| 1.5x3.0 (3.3x6.6) | 2 255 (89) | 4 550 (179) | 3 150 (124) | 75/100 | 9.2 |
| 1.8x3.6 (6x12) | 2 660 (105) | 5 560 (219) | 3 500 (138) | 132/177 | 12.8 |
| 2.1x3.6 (7x12) | 3 150 (124) | 5 830 (230) | 4 400 (173) | 132+75/ | 22.0 |
| | | | | 177+100 * | |

| SRR Rod mill<br>Mill size m (ft)<br>DxL | H<br>mm (inch) | L<br>mm (inch | W<br>mm (inch | Power motor<br>kW/Hp | Weight (empty)<br>ton |
|---|---|---|---|---|---|
| 0.6x0.9 (2x3) | 1 110 (44) | 1 830 (72) | 1 220 (48) | 2.2/3 | 1.0 |
| 1.0x1.5 (3.3x5) | 1 635 (64) | 2 700 (106) | 1 850 (73) | 11/15 | 3.0 |
| 1.2x2.4 (4x8) | 1 970 (78) | 3 670 (144) | 2 740 (108) | 30/40 | 6.2 |
| 1.5x3.0 (3.3x6.6) | 2 255 (89) | 4 550 (179) | 3 150 (124) | 75/100 | 10.0 |
| 1.8x3.6 (6x12) | 2 790 (110) | 5 600 (220) | 3 900 (154) | 55+55/ | 14.5 |
| | | | | 74+74* | |

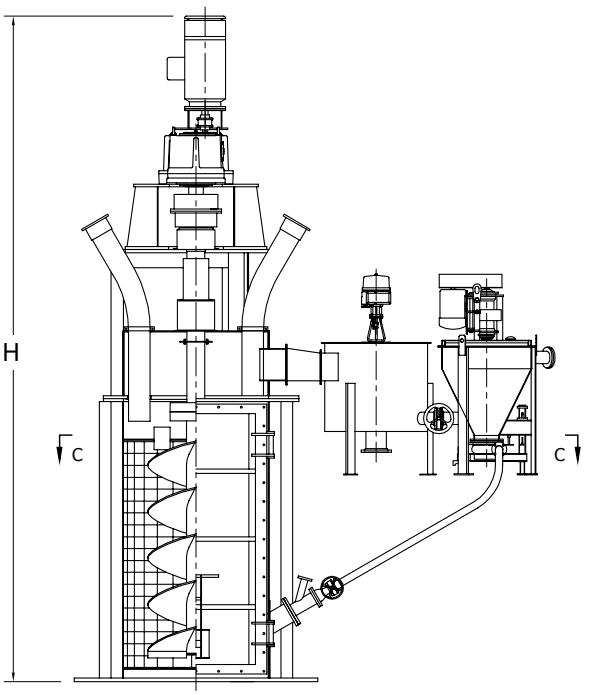
**Dual drive*

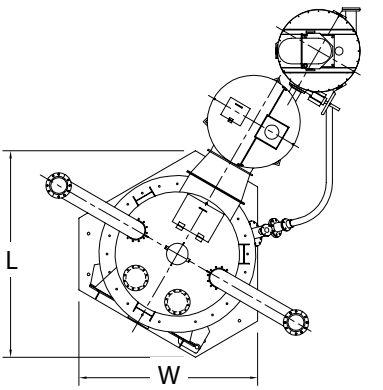
## *VERTIMILL*®

Type WB (**W**et grinding – **B** design) is larger in diameter, but also have larger diameter, screw turning at lower speed and shorter overall height compared with the LS type. They are designed to operate at full motor power. Orebed lining.

Regarding type LS (Lime Slaking) for size reduction and slaking of lime, see 3:52





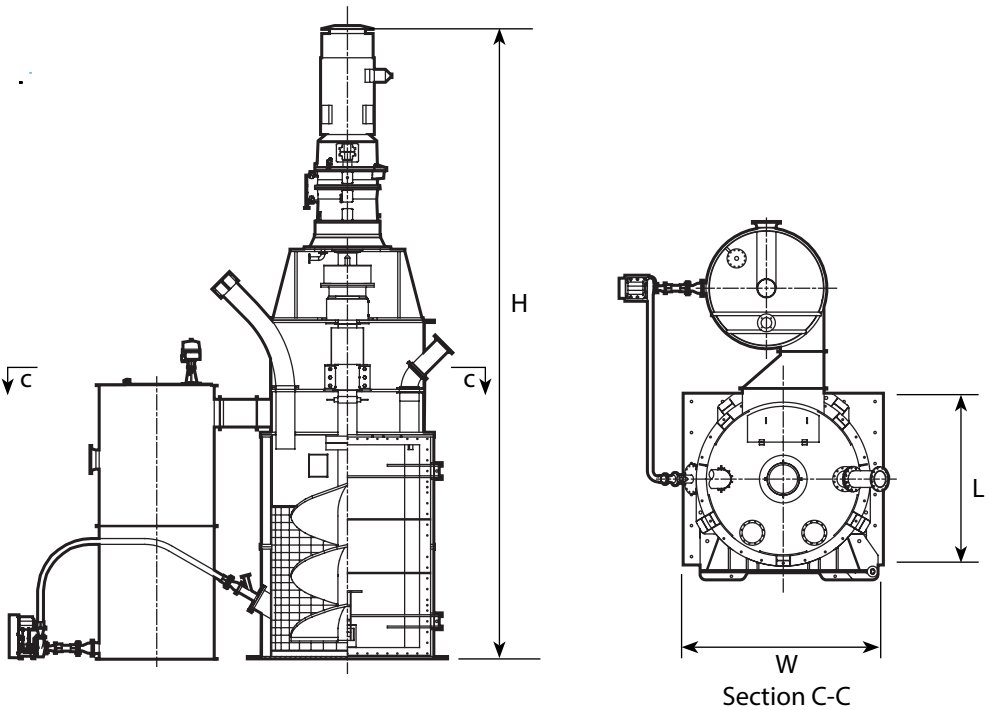




SECTION C-C

| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/Hp | Weight (empty) ton |
|---|---|---|---|---|---|
| VTM-15-WB | 7 060 (278) | 1 520 (60) | 1 320 (52) | 11/15 | 5.5 |
| VTM-20-WB | 7 180 (283) | 1 520 (60) | 1 320 (52) | 15/20 | 5.9 |
| VTM-40-WB | 7 460 (294) | 1 780 (70) | 1 520 (60) | 3040 | 8.2 |
| VTM-60-WB | 7 600 (299) | 1 780 (70) | 1 520 (60) | 45/60 | 8.8 |
| VTM-75-WB | 7 900 (311) | 1 960 (77) | 1 700 (67) | 56/75 | 12.5 |
| VTM-125-WB | 9 270 (365) | 2 670 (105) | 2 310 (91) | 93/125 | 17.9 |
| VTM-150-WB | 9 780 (385) | 2 670 (105) | 2 310 (91) | 112/150 | 19.6 |
| VTM-200-WB | 9 780 (385) | 2 670 (105) | 2 310 (91) | 150/200 | 20.5 |
| VTM-250-WB | 9 650 (380) | 3 660 (144) | 3 180 (125) | 186/250 | 33.8 |
| VTM-300-WB | 9 650 (380) | 3 660 (144) | 3 180 (125) | 224/300 | 35.7 |
| VTM-400-WB | 11 320 (446) | 3 910 (154) | 3 380 (133) | 298/400 | 52.7 |
| VTM-500-WB | 12 070 (475) | 3 860 (152) | 3 780 (149) | 373/500 | 66.1 |

## *VERTIMILL®*






Section C-C

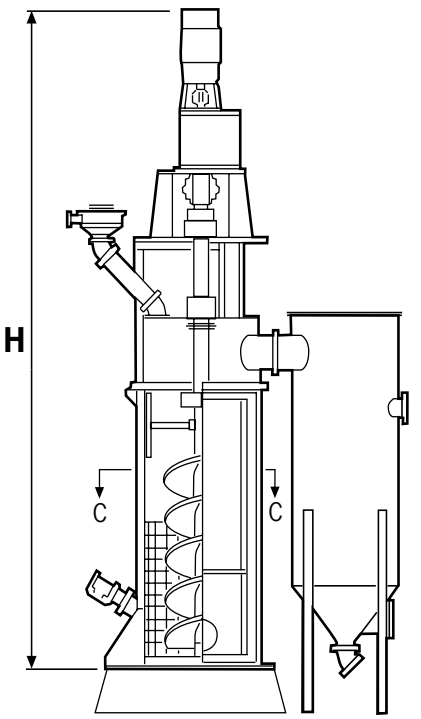
| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/Hp | Weight (empty) ton |
|---|---|---|---|---|---|
| VTM-650-WB | 12 270 (483) | 3 250 (128) | 3 860 (152) | 485/650 | 82.6 |
| VTM-800-WB | 13 460 (530) | 3 560 (140) | 4 060 (160) | 597/800 | 100.4 |
| VTM-1000-WB | 13 460 (530) | 3 660 (144) | 4 270 (168) | 746/1 000 | 116.1 |
| VTM-1250-WB | 13 460 (530) | 4 090 (161) | 4 520 (178) | 932/1 250 | 125.4 |
| VTM-1500-WB | 14 220 (560) | 4 370 (172) | 4 570 (180) | 1 118/1 500 | 167.0 |
| VTM-3000-WB | 17 590 (692) | 6 820 (268) | 6 880 (271) | 2 237/3 000 | 343.0 |
| VTM-4500-C | 18 600 (732) | 6 820 (268) | 6 880 (271) | 3355/4500 | 367.0 |

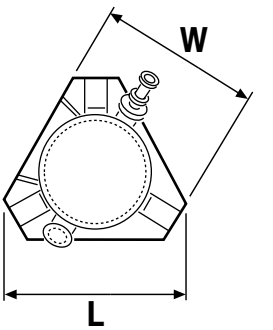
# *VERTIMILL*®

## *Type LS (Lime Slaking) for size reduction and slaking of lime*

Regarding type WB (Wide body) for grinding operations only, see: 3:50-51.



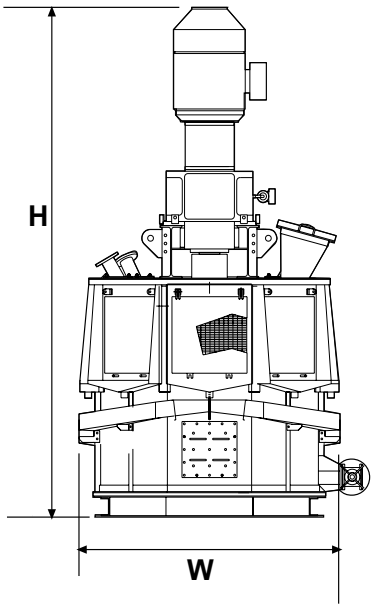


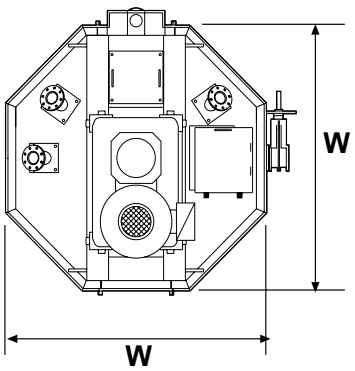




SECTION C-C

| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/Hp | Weight (empty) ton |
|---|---|---|---|---|---|
| VTM-20-LS | 7 060 (278) | 1 520 (60) | 1 320 (52) | 15/20 | 5.5 |
| VTM-30-LS | 7 180 (283) | 1 520 (60) | 1 320 (52) | 22/30 | 5.9 |
| VTM-50-LS | 7 460 (294) | 1 780 (70) | 1 520 (60) | 37/50 | 8.2 |
| VTM-100-LS | 7 900 (311) | 1 960 (77) | 1 700 (67) | 45/60 | 8.8 |
| VTM-150-LS | 8 740 (344) | 2 670 (105) | 2 310 (91) | 75/100 | 12.5 |
| VTM-200-LS | 9 780 (385) | 2 670 (105) | 2 310 (91) | 112/150 | 17.9 |
| VTM-300-LS | 10 160 (400) | 3 660 (144) | 3 180 (125) | 150/200 | 19.6 |
| VTM-400-LS | 11 320 (446) | 3 910 (154) | 3 380 (133) | 224/300 | 50.0 |

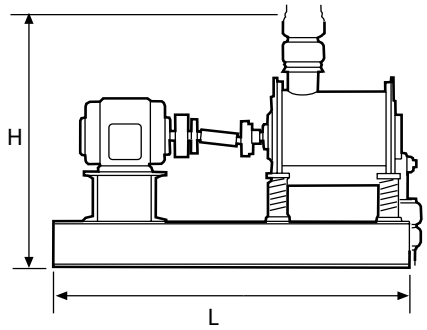
## *Stirred media grinding mIll*

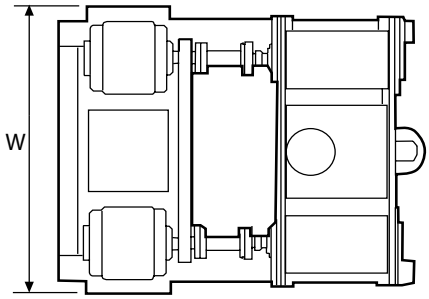



| Model | Power motor kW (HP) | H mm (inch) | W mm (inch) | Weight (empty) kg (lb.) |
|---|---|---|---|---|
| SMD-90 | 90 (120) | 4215 (166) | 2130 (84) | 4020 (8 863) |
| SMD 185 | 185 (250) | 4 350 (171) | 2 275 (90) | 7 200 (15 875) |
| SMD 355 | 355 (475) | 5 990 (236) | 2 800 (110) | 13 450 (29 650) |
| SMD 1100 | 1 100 (1475) | 4 825 (190) | 4 220 (166) | 27 500 (60 630) |

## *Vibrating ball mill*




| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/Hp | Weight (empty) ton |
|---|---|---|---|---|---|
| VBM 1518* | 1 120 (44) | 1 780 (70) | 1 350 (53) | 2x5.6/2x7.5 | 1.2 |
| VBM 3034** | 1 680 (66) | 2 790 (110) | 2 130 (84) | 2x37/2x50 6.2 | |

* Grinding chamber diameter15”(380mm), length 18”(460mm)

** Grinding chamber diameter30”(760mm), length 34”(860mm)

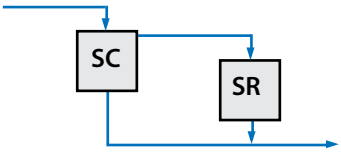
## Size control – Introduction

With size control we understand the process of separating solids into two or more products on basis of their size. This can be done dry or wet.

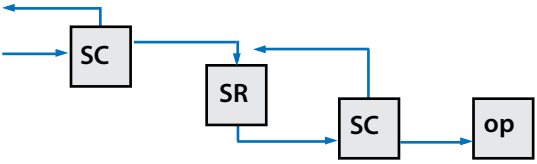
As mentioned earlier neither crushers nor grinding mills are too precise in their size reduction job and a lot of size fractions are misplaced. By using optimum size control the result can be improved both regarding capacity, size and particle shape.

## Size control by duties

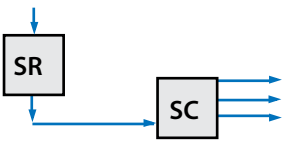
**To prevent** undersize in the feed from blocking the next size reduction stage (scalping)




**To prevent** oversize from moving into the next size reduction or operation stage (circuit sizing)



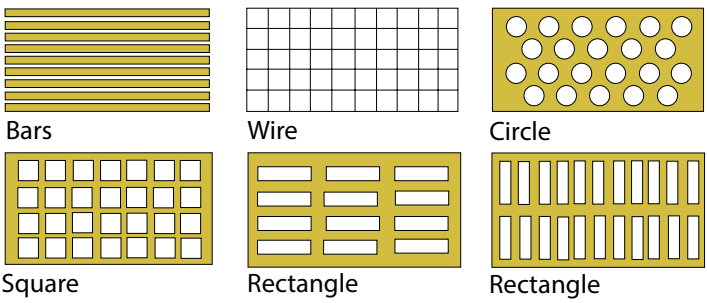

**To prepare** a sized product (product sizing)



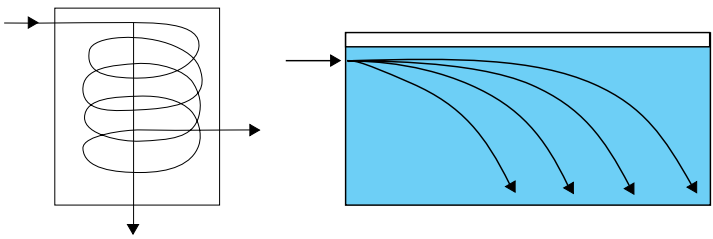

## Size control by methods

In mineral processing practices we have two methods dominating size control processes:

- **Screening** using a geometrical pattern for size control.



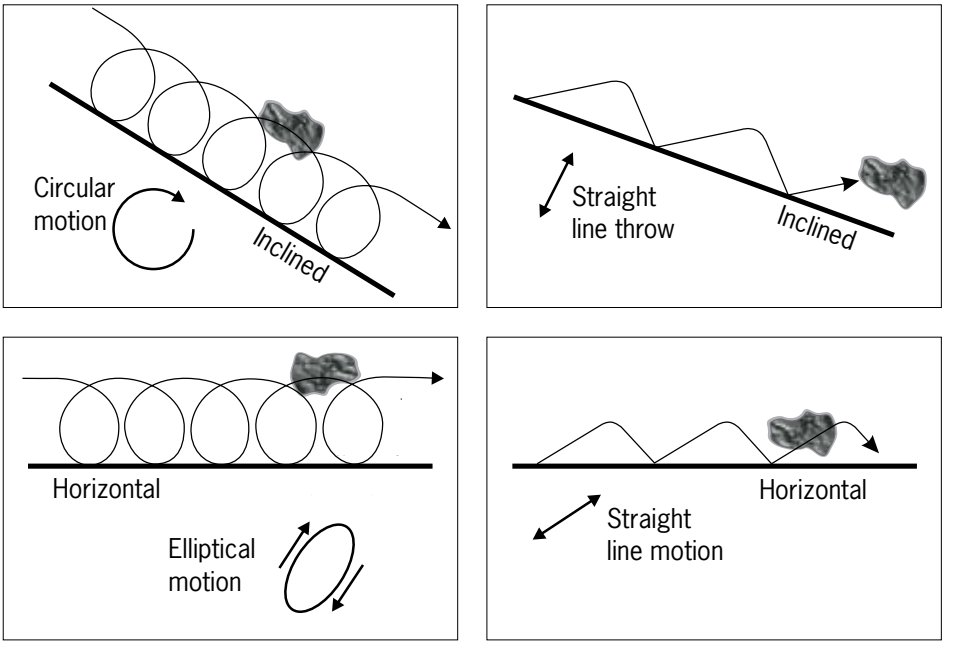

- **Classification** using particle motion for size control.



## Screens

Performance of screens will fall back on three main parameters:
**Motion – Inclination – Screening media**

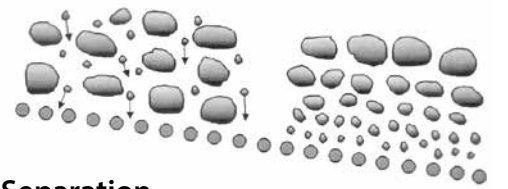
### Screen motions



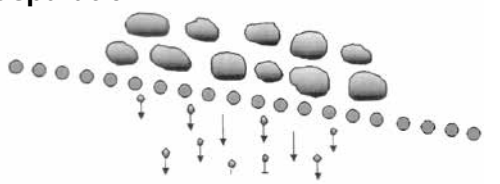

## Screening by stratification

By building up a material bed on a screen deck the material will stratify when the motion of the screen will reduce the internal friction in the material. This means that the finer particles can pass between the larger ones giving a sharp separation.

**Stratification**

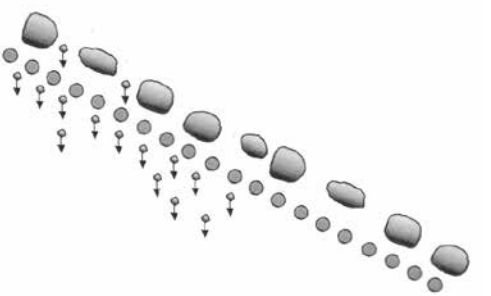


**Separation**



## Screening by free fall

If we use the double inclination used for stratification (from 10-15 up to 20-30 degrees) we are in free fall, meaning that no particle layer can build up on the screen deck. The particles will now be sized directly via the screening media, giving a higher capacity, (or a more compact installation), but also less sharpness in separation. Optimal use when a large amount of fines shall be removed fastly.



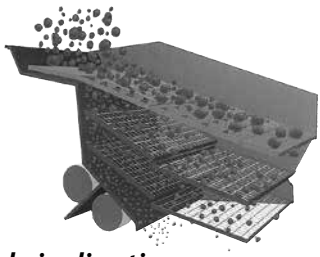
## Screen types

There are many types of screens, but they can be reduced to the four types shown below. Of these types approx. 80 % used worldwide are of type **single inclination**, stratification screens. The other are of type **double, triple** or **multiple** inclination, where screening by stratification and free fall are combined for different applications.

### *Single inclination*

- Stratification screen
- Circular (15 deg.)
- Linear 0 – 5 (deg.)
- Still the leader in selective screening

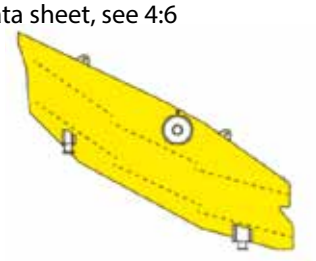
Data sheet, see 4:6



### *Double inclination*

- Free fall
- Compact - high capacity paid for by lower selectivity
- Typical in circuit screening

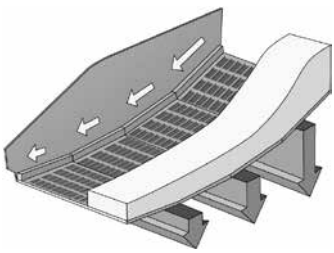
Data sheet, see 4:7



### *Triple inclination*

- Combine capacity and selectivity
- Typical control screen for advanced product fractions

Data sheets see 4:8



### *Multiple inclination ("banana screen")*

- Effective "Thin-layer" screen
- Popular in coal and metallic mining

Data sheets, see 4:8

## Screen capacities

Sizing of screens is a time consuming process to be done by specialists. To get an idea about capacities we can use the figures below. They refer to screening by stratification using wire mesh as screening media.

| Feed through screen deck (t/h) | | | | |
|---|---|---|---|---|
| **Separation** | **3.6 x 1.5 m** | **4.2 x 1.8 m** | **4.8 x 2.1 m** | **6.0 x 2.4 m** |
| **(mm)** | **5.4 m²** | **7.6 m²** | **10.0 m²** | **14.4 m²** |
| 2 | 20 | 30 | 45 | 65 |
| 5 | 50 | 70 | 95 | 135 |
| 8 | 75 | 105 | 140 | 180 |
| 12 | 100 | 145 | 200 | 230 |
| 16 | 125 | 180 | 230 | 270 |
| 25 | 175 | 250 | 300 | 350 |
| 32 | 200 | 290 | 350 | 400 |
| 50 | 270 | 370 | 430 | 500 |
| 90 | 370 | 460 | 550 | 640 |

**Example:**

Single deck screen. Feed size 50% - 2 mm. Feed capacity 90 t/h, cut 2 mm.

**Select:** a 10 m² screen deck.

# Selection of screening media

Selection of the correct size and type of screen is important. Equally important is the selection of the screening media. This refers not only to a correct aperture related to the "cut size ", but also to the wear in operation of these screens. Below a short selection guide to screening media can be found.

## Rubber or polyurethane?

| Feed size | Select | Because |
|---|---|---|
| >35 mm dry | Rubber 60 sh | Absorbes impact<br>Resistant to sliding abrasion |
| <0-50 mm wet | Polyurethane | Very good against sliding abrasion<br>Accurate separation |
| <40 mm dry/moist | Rubber 40 sh (soft) | Very flexible<br>Prevents blinding |
| **Look out for:** | Oil in rubber applications<br>Hot water or acids in PU-applications | |

## What thickness?

General rule for min. thickness

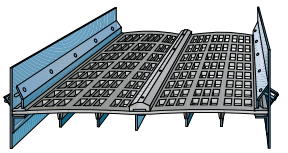
$$\frac{\text{Max feed size}}{4} = \text{Panel thickness}$$

What happens if we go...?

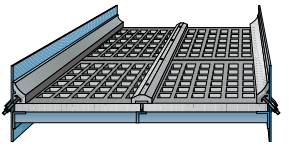
| THINNER | | THICKER |
|---|---|---|
| + | Capacity | – |
| + | Accuracy | – |
| – | Service life | + |
| – | Blinding/Pegging Tendency | + |

N.B.: Thickness should not exceed required product size

## What type of panel

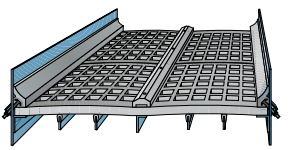


***Tension mats with hooks** fits all screens designed with cambered decks and tensioning rails.*

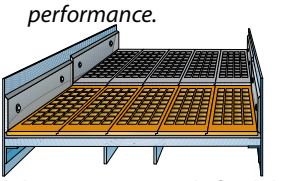


***Self supporting panels**, for screens of open frame design for tough applications .*

***Wire mesh panels** offer superior open area and are quickly available.*

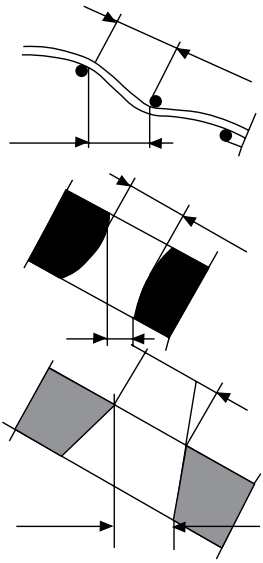


***Bolt down panels**, pre-tensioned for easy installation and guaranteed screening performance.*



***Modular systems** provide flexibility in wear material/hole configuration combinations.*

## *What hole size? (Inclined deck)*



**General guideline for wire mesh:**

"Required product size plus 5 – 10%"

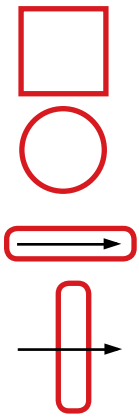
**General guideline for rubber panels:**

"Required product size plus 25 – 30%"

**General guideline for PU panels:**

"Required product size plus 15 – 20%"

## *What type of hole?*



The standard choice

For improved service life (coarse screening)

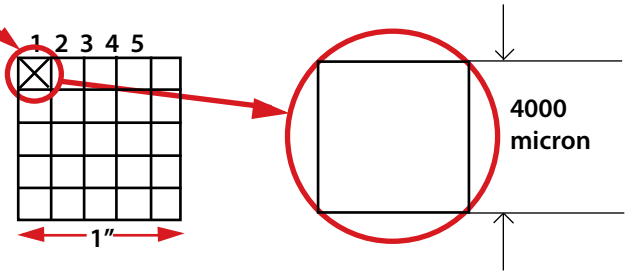
For improved capacity

For improved accuracy and dewatering

## *Particle size – Mesh or Micron?*

| mesh* | micron | mesh | micron | mesh | micron |
|---|---|---|---|---|---|
| 2½ | 8000 | 14 | 1180 | 80 | 180 |
| 3 | 6700 | 16 | 1000 | 100 | 150 |
| 3½ | 5600 | 20 | 850 | 115 | 125 |
| 4 | 4750 | 24 | 710 | 150 | 106 |
| 5 | 4000 | 28 | 600 | 170 | 90 |
| 6 | 3350 | 32 | 500 | 200 | 75 |
| 7 | 2800 | 35 | 425 | 250 | 63 |
| 8 | 2360 | 42 | 355 | 270 | 53 |
| 9 | 2000 | 48 | 300 | 325 | 45 |
| 10 | 1700 | 60 | 250 | 400 | 38 |
| 12 | 1400 | 65 | 212 | 500 | 25 |

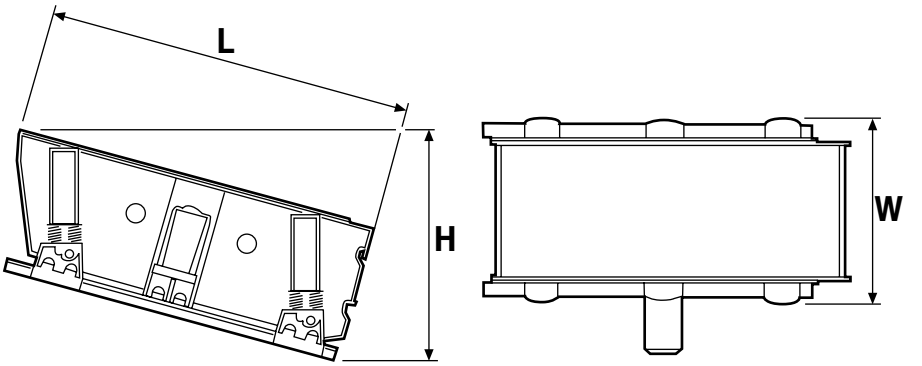
*Taylor serie (US)




Mesh number = the number of wires per inch or the number of square apertures per inch

## *Single inclination screen – Circular motion*






Dimensions at 15° inclination

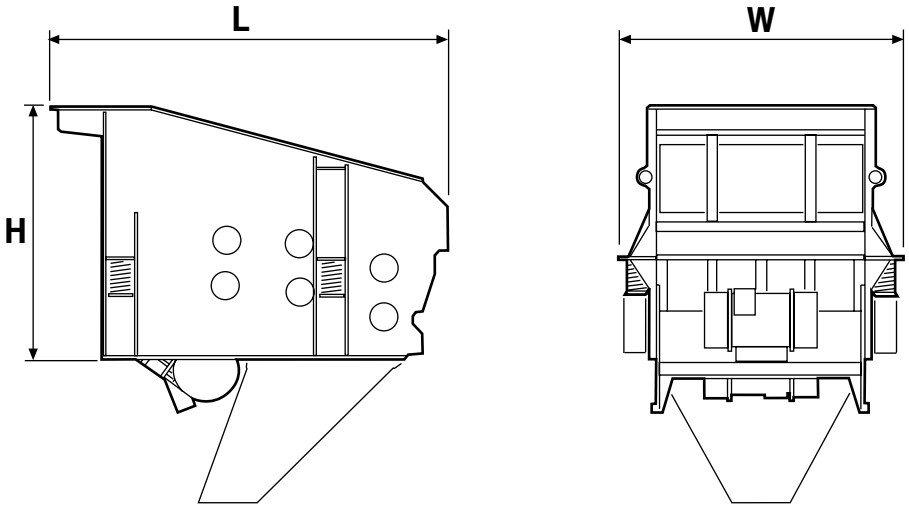
| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/hp | Weight ton |
|---|---|---|---|---|---|
| VFS 36/15 2d | 2 700 (106) | 4 465 (176) | 2 230 (88) | 11/15 | 3.7 |
| VFS 42/18 2d* | 2 965 (117) | 5 065 (199) | 2 530 (100) | 15/20 | 4.5 |
| VFS 48/21 2d | 3 100 (122) | 5 665 (223) | 2 830 (111) | 18.5/25 | 5.5 |
| VFS 36/15 3d | 3 065 (121) | 4 465 (176) | 2 230 (88) | 15/20 | 4.7 |
| VFS 42/18 3d | 3 220 (127) | 5 065 (199) | 2 530 (100) | 18.5/25 | 5.8 |
| VFS 48/21 3d | 3 530 (139) | 5 665 (223) | 2 830 (88) | 22/30 | 7.5 |
| VFSM 42/18 2d** | 2 900 (114) | 5 200 (205) | 2 530 (100) | 18.5/25 | 5.6 |
| VFSM 48/21 2d | 3 050 (120) | 5 800 (228) | 2 830 (111) | 22/33 | 7.0 |
| VFSM 60/24 2d | 3 550 (140) | 7 000 (276) | 3 340 (131) | 2x18.5/2x25 | 10.8 |
| VFSM 48/21 3d | 3 425 (135) | 5 800 (228) | 2 830 (88) | 2x18.5/2x25 | 8.5 |
| VFSM 60/24 3d | 4 305 (170) | 7 000 (276) | 3 340 (131) | 2x22/2x33 | 14.2 |

* VFS 42/18 2d = screen deck dimension 4.2m x1.8m (165"x70"), double deck

**VFSM 42/18 2d = same as above but heavy duty version

Screening area calculated from screen type ex. VFS 42/18; 4.2x1.8 = **7.6 m²** x11= **82ft²**

## *Double inclination screen – Linear motion*

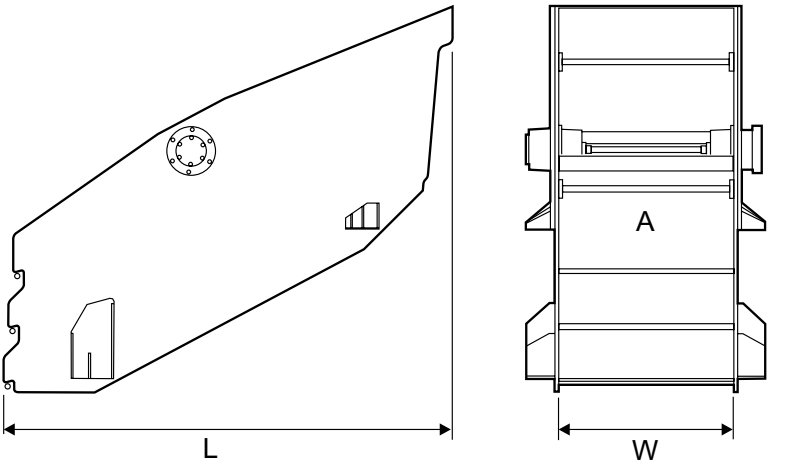





| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/hp | Weight ton | Max feed mm/inch |
|---|---|---|---|---|---|---|
| VFO 12/10 2d | 1 450 (57) | 1 330 (52) | 435 (17) | 2x1.3/2x1.7 | 1.0 | 120/5 |
| VFO 20/12 2d | 1 515 (60) | 2 380 (94) | 1 700 (67) | 2x2.3/2x3.1 | 1.6 | 150/6 |
| VFO 20/12 3d | 1 515 (60) | 2 380 (94) | 1 700 (67) | 2x2.3/2x3.1 | 1.7 | 150/6 |
| VFOM 12/10 3d* | 1 390 (55) | 1 460 (579 | 1 426 (56) | 2x2.3/2x3.1 | 1.3 | 300/12 |
| VFOM 20/12 3d | 1 915 (75) | 2 980 (117) | 1 720 (68) | 2x4.0/2x5.4 | 2.7 | 300/12 |

* VFOM, heavy-duty version with dual springs at feed and discharge ends

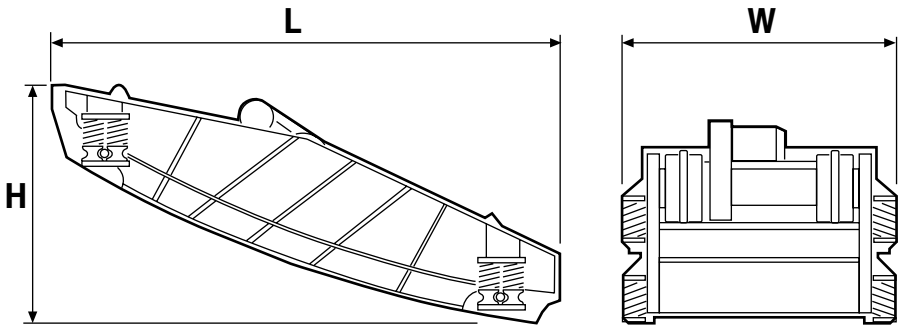
## *Triple inclination screen – Linear motion*




| Model | L mm (inch) | W mm (inch) | A $m^2$ (Sq. ft.) | Power motor kW /HP | Weight ton |
|---|---|---|---|---|---|
| TS 2.2* | 5 830 (230) | 1 530 (60) | 7.5 (80) | 15/20 | 6 |
| TS 2.3* | 5 830 (230) | 1 530 (60) | 7.5 (80) | 15/20 | 8 |
| TS 3.2 | 6 330 (249) | 1 839 (72) | 11 (116) | 22/30 | 8 |
| TS 3.3 | 6 330 (249) | 1 839 (72) | 11 (116) | 22/30 | 10 |
| TS 4.2 | 6 350 (250) | 2 445 (96) | 15 (156) | 30/40 | 9 |
| TS 4.3 | 6 350 (250) | 2 445 (96) | 15 (156) | 30/40 | 12 |
| TS 5.2 | 8 595 (338) | 2 445 (96) | 20 (215) | 30/40 | 16 |
| TS 5.3 | 8 595 (338) | 2 445 (96) | 20 (215) | 2x22/2x30 | 20 |
| TS 6.2 | 8 734 (344) | 3 045 (120) | 25 (269) | 2x22/2x30 | 20 |
| TS 6.3 | 8 736 (344) | 3 045 (120) | 25 (269) | 2x30/2x40 | 24 |

* TS 2.2 = 2 decks and TS 2.3 = 3 decks screen

## *Multiple inclination screen – Linear motion (Banana screen)*




| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power motor kW/hp | Weight ton |
|---|---|---|---|---|---|
| MF 1800x6100 1d | 2 703 (107) | 6 430 (253) | 2 555 (101) | 22/30 | 6.7 |
| MF 2400x6100 1d | 2 691 (106) | 6 431 (253) | 3 166 (125) | 30/40 | 8.5 |
| MF 3000x6100 1d | 2 897 (114) | 6 614 (260) | 3 774 (149) | 45/60 | 11.5 |
| MF 3000x6100 2d | 4 347 (171) | 6 759 (266) | 3 774 (149) | 45/60 | 17.0 |

## *Classification – Introduction*

For size control of particles finer than 1 mm, we are moving out of the practical range of conventional screens.

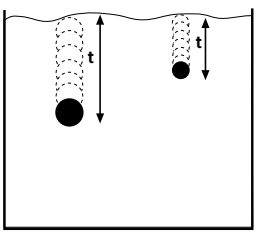
Classification is the process of separating particles by size into two or more products according to their behavior in air or water (liquids).

Classification methods

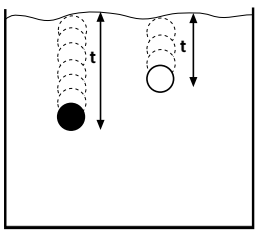
- **Wet** classification with **hydrocyclones** using separation by centrifugal force covering the size range of 100 –10 micron (typical)
- **Wet** classification with **spiral classifiers** using separation by gravity covering the size range of 100 – 1000 micron (typical)
- **Dry** classification using separation by centrifugal force covering the range of 150 – 5 micron (typical).



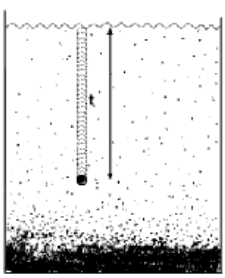
## *Wet classification – fundamentals*



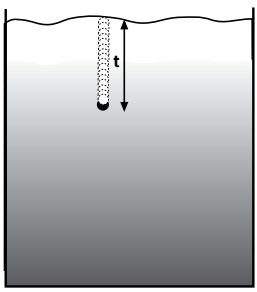

Coarse particles move faster than fine particles at equal density




High density particles move faster than low density particles at equal size




Free movement

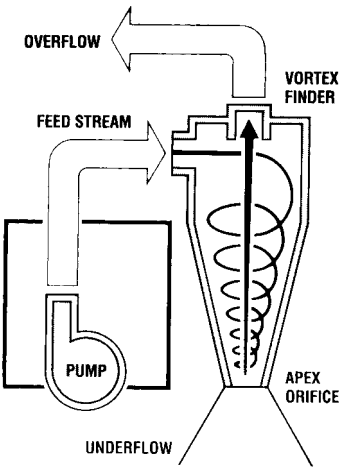



Hindered movement

If a particle has no interference from other particles it moves faster than a particle surrounded by other particles due to increased density and viscosity of the slurry. This is called **free** and **hindered** movement and is valid both for gravity and centrifugal classification.

## *Hydrocyclone**

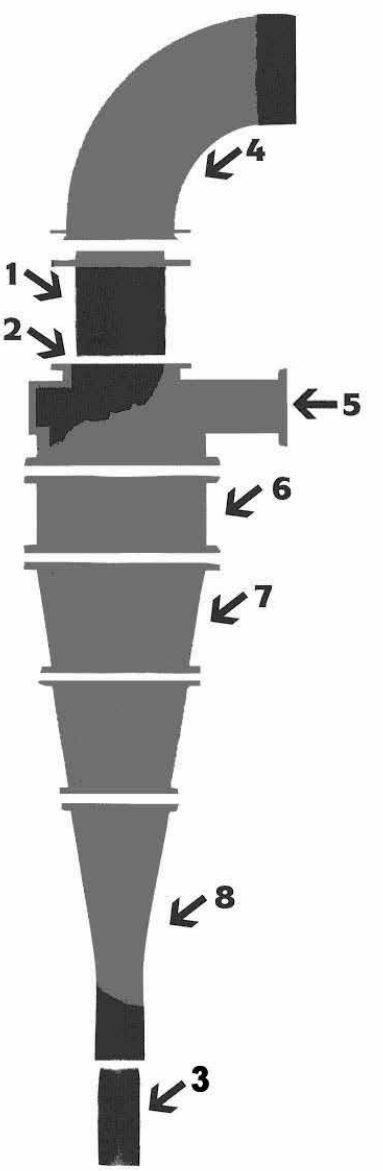
Centrifugal forces classify solids by size (mass).
High mass particles closer to outer wall reporting to underflow.
Low mass particles closer to the centre reporting to overflow.






### *Hydrocyclone design*

1. Vortex finder
2. Inlet head
3. Spigots (apex)
4. Overflow elbow
5. Feed inlet
6. Barrel
7. Cones
8. Cone extension




### *Hydrocyclone applications – more than size control*

Although the hydrocyclone by nature is a size controlling machine the number of applications in mineral are many

- Classification in grinding circuits
- Dewatering and thickening
- Desliming and washing
- Enrichment of heavy minerals (DMS)
- a.o.

* Contact Metso for further information about this product.

# *Spiral classifier**

By combining a gravity settler of rectangular section with a sloped transport spiral for the sediment – we have a spiral classifier.

## *Spiral classifier – Nomenclature*

24" Model 100-MF-SP

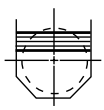
- Pitch – Single (SP) or Double (DP)
- Tank Style – Straight (ST), Modified Flare (MF) and Full Flare (FF)
- Spiral Submergence Model – 100%, 125% or 150%
- Spiral Diameter



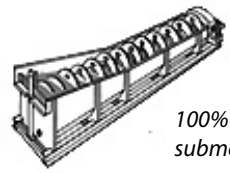
## *Spiral classifier – Design*

By combining the proper submergence of the spiral as shown in the drawings of the three models at right with one of the three tank designs a choice of combinations are possible. Thus the selection can be tailored to suit each problem. The proper combination of pool depth, area and spiral construction, result in controlled turbulence for accurate size separations or efficient washing or dewatering as desired.

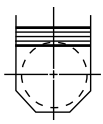
The required pool area is balanced with the sand raking capacity of the spiral by the design of the tank. Tank designs to suit specific applications are shown below.



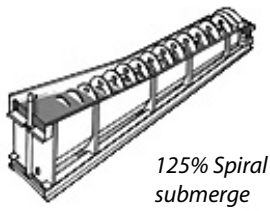
*Model 100*



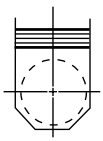
*100% Spiral submerge*



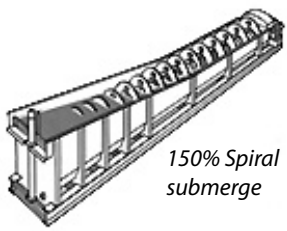
*Model 125*



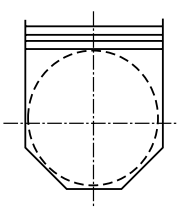
*125% Spiral submerge*



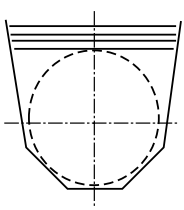
*Model 150*



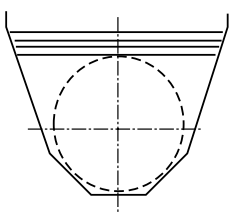
*150% Spiral submerge*



*Straight side tank*



*Modified flare tank*



*Full flare tank design*

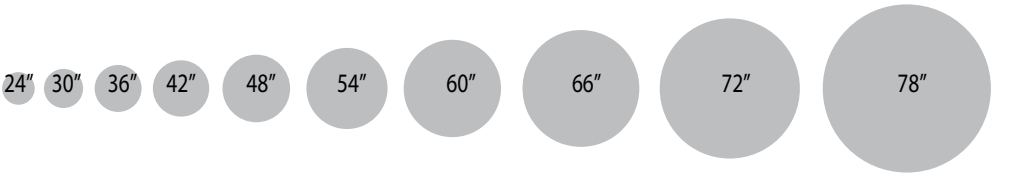
**Straight side:** For coarse separations.

**Modified flare:** Increases pool area for intermediate to fine separations and for washing and dewatering.

**Full flare:** Maximum pool area for fine to very fine separations and for washing and dewatering where large volumes of water are to be handled.

Sand raking and conveying is usually a major consideration in any classifier application, and the full range of spiral diameters available cover all requirements. Each of these units is designed for high efficiency and greater raking capability due to the increased lead or helix angle of the spiral. This increased lead angle results in improved conveying efficiency and greater conveying capacity.

## Size control

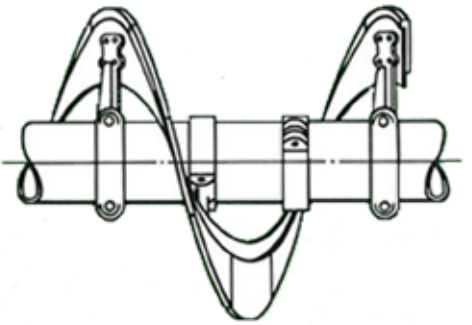


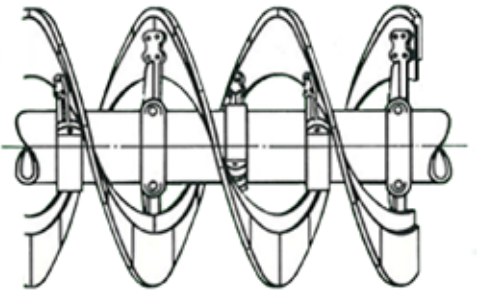

**Single pitch:**

Single pitch spirals are available on all sizes of classifier and consist of one continuous spiral ribbon.

**Double pitch:**

The double pitch spiral has twice the raking capacity of a single pitch assembly and consists of two duplicate spiral ribbons. This construction is available for all sizes of classifier.





* Contact Metso for further information about this product.

# Dry classification – Introduction

## General

The Static and dynamic air classifiers offer solutions in combination with ancillary equipment to meet the demands of almost any dry separation requirement. This equipment offers solutions to the mining, construction, industrial mineral and chemical industries. A wide range of separations are available from 1.4mm (12#) down to 10µm (#1250) with separation efficiencies of up to 95%. Full, flexible engineering design and support is available to ensure full integration.

Classifier throughputs range from lab size units to applications processing hundreds of tones per hour. Application, feed type, fineness of classification and classification accuracy required influence the allowable moisture in the feed which typically ranges from 2.5% to below 1% dependant on the process.

The static and dynamic classifiers offer tailored solutions for a wide range of applications Machine sizing and selection is normally done in consultation with the product line to ensure correct application and matching with required ancillary equipment.



## Typical applications

**Mining**

Dry grinding
Arid zone mining

**Construction**

Concrete sand
Asphalt sand
Mineral filler

**Industrial Minerals**

Silicates
Graphite
Glass
Ceramics
Salts
Feldspar
Talc
Chalk
Diatomaceous earth
Gypsum
Betonite

**Cement and Pozzolan**

Fly Ash
Slag
Cement
Other pozzolan

**Chemical**

Soda Ash
Metallurgical processing additives
Cosmetics
Stearate (salts)
Fertilizer
Bicarbonate (FGD)

# Static classifiers

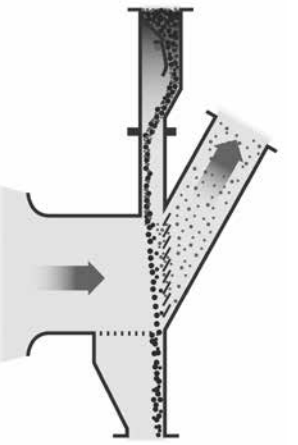
Static air classifiers achieve accurate separations from 1.4 mm (12 mesh) to 20µm (635 mesh). The static air classifiers are designed to achieve extremely accurate separations even though they contain no moving elements in the airstream.

This is achieved through airflow design and use of recirculating, secondary airflow on finer separations to scrub the coarse product before it is discharged. The re-circulating airflow is adjustable so the amount of undersize retained is also adjust-able. This provides fine tuning of the end products so exact product specifications can be achieved. The design of the recirculating systems mean that adjustments can be done during production and results are instant.

The static design of these classifiers offers excellent wear characteristics through the use of ceramic linings whose lifetimes are measured in years, low maintenance requirements and low power draw.

## *Gravitational classifiers*

The gravitational classifiers are designed for coarser separations in the range of 1.4mm/150µm (12/100#). The feed material is spread over the width of the classifier and drops as a continuous feed curtain through the top of the classifier. Low velocity air enters the classifier through the front inlet and is drawn through the feed curtain which is dropping in front of the angled vanes on the air outlet.



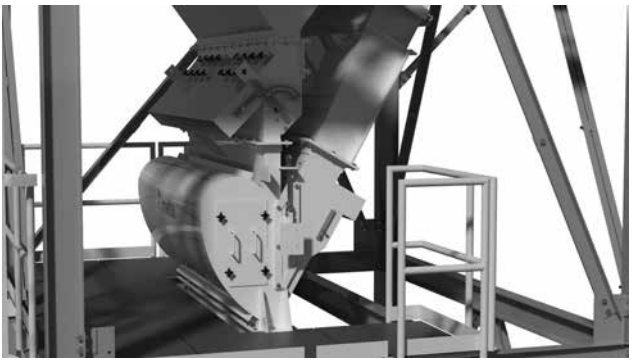
*Gravitational classifier*

The air stream enters the feed curtain perpendicularly and draws the finer particles from the curtain of material. The air current then draws the particles up almost vertical through the vane rack. Gravitational classifiers are suitable for closing grinding circuits, de-dusting of coarser feeds, reducing a high feed loading rate to a finer classifier and it can also be used as a density separator if the specific gravity difference of the product : waste ratio is > 5:1.

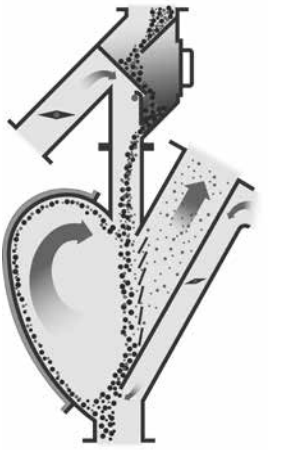
## *Gravitational inertial classifiers*

These units combine gravitational, inertial, centrifugal and aerodynamic forces to achieve separations from 300 µm /63µm (50/230#). The feed material is spread over the width of the classifier and drops as a continuous feed curtain through the top of the classifier. The primary air also enters the top of the classifier in a downward direction with the feed. The air is drawn through the feed curtain and then through a 120° change in direction and exits through the vanes carrying undersize particles with it.

The coarser particles that are not drawn away drop down to where a secondary air flow is drawn into the classifier. The coarse particle curtain is scrubbed by this secondary air with the finer fraction being drawn by the secondary airflow back into the primary feed curtain. By making simple adjustments to the secondary air damper the end products can be modified. As there are no moving parts within the material flow stream significantly reduces maintenance requirements. Use of ceramic lining throughout the classifier gives impressive wear resistance.

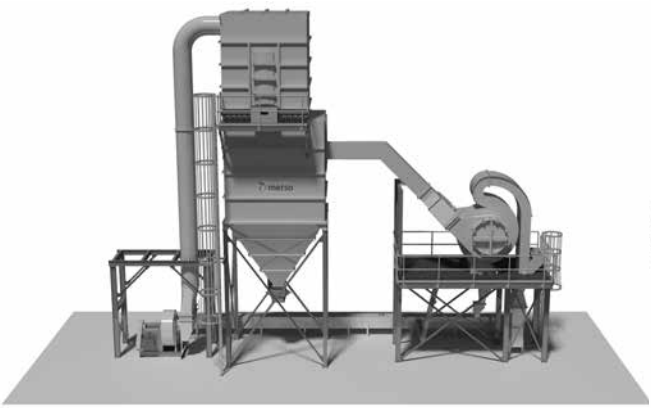


*Gravitational inertial classifier*



## *Centrifugal classifiers*

The centrifugal classifier utilizes centrifugal forces in a similar way to cyclones to induce fine particle separation. The classifier is capable of separations in the range of 100/15µm (140/800#). The classifier has widespread acceptance in industrial minerals, cement and fly ash applications where its high degree of separation accuracy and exceptionally low maintenance requirements exceeds operator expectations. The classifier is used in conjunction with a dust collector and system fan. Systems can have an open or closed loop dependant on application and numerous dust collector and silo storage options.



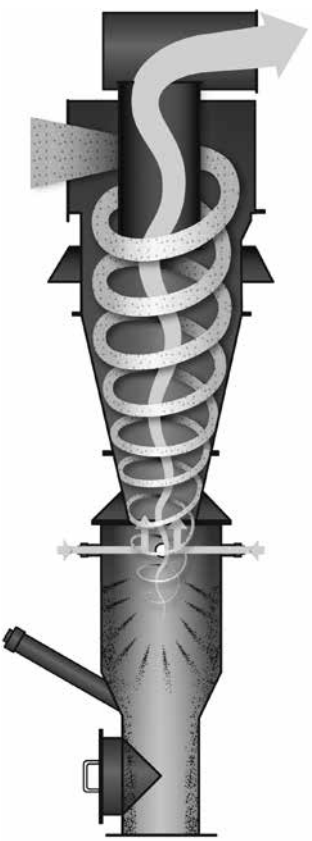
*Centrifugal classifier, dust collector and fan*

## *Cyclonic ultrafine classifiers*

Specially designed high efficiency cyclonic classifiers with controllable reverse air flow systems can achieve adjustable ultrafine classifications. The cyclonic ultrafine classifier is a hybrid air cyclone that combines cyclone and classifier designs to separate very fine particles. In conventional air cyclones, the aim is to remove as much of the particulate from the airstream as possible. However the cyclonic ultrafine classifier is designed to allow the finest particles to be removed in the ascending vortex.

This separation is achieved by introducing a reverse airflow into the specially designed disengaging hopper that weakens the descending vortex and creates a stronger entraining force in the ascending vortex that draws the required particles away to the fines collector. Control of the separation point is achieved by varying the percentage of reverse airflow relative to the total air.

The cyclonic ultrafine classifier is designed to achieve separations in the region of 50µm (#270) to 10µm (#1250) with a top feed size of 5mm (#4). The cyclonic ultrafine classifiers are very low maintenance even on highly abrasive feeds. The unit contains no moving parts and adjustments can be made on-line. The range of manufacturing materials available includes abrasion resistant, stainless and mild steels and aluminum. For abrasive applications, ceramic lining is available which give exceptional sliding wear resistance.



*Cyclonic ultrafine classifier*

## Dynamic classifiers

The dynamic air classifiers are built to suit a range of applications and systems and have been often installed on air swept mills circuits. The gyrotor, a rotating vane air classifier, separates dry, solid, homogenous particles by size. Delta-sizers are designed for accurate separation of dry feeds at high efficiency and low power consumption on a continuous basis.

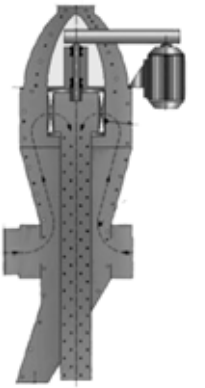
### Gyrotors

Utilizes a rotating vane to separate dry solid particles by size for separations for 500/45µm (35/325 mesh). Gyrotors can be integrated into a conventional closed or open dry grinding circuit. Gyrotors can also be utilized in a classification only system complete with cyclone, fan, dust collector and rotary air locks.

*Gyrotor*

### Delta-sizers

Delta-sizers are designed for accurate separation of dry feeds at high efficiency and low power consumption on a continuous basis. The Metso Delta-sizer can be integrated into a conventional closed or open dry grinding circuit; or utilized in a classification only system complete with cyclone, fan, dust collector and rotary air locks.



*Delta-sizer*

## Ancillary air solutions

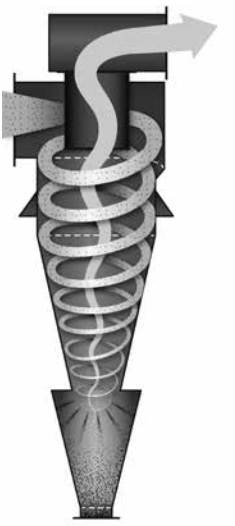
Ancillary air solutions provide the systems required for the correct operation of the classifier equipment as well as offering other dry solution capabilities.

### High efficiency cyclones

High efficiency cyclone technologies are specifically tailored to the needs of the mining, industrial mineral and construction industries.

The high efficiency cyclones are the product of significant development with the aim of achieving extremely high levels of particle removal from the airstream. The unique inlet scroll is designed with a smooth flow elbow to eliminate currents perpendicular to the main direction of gas flow that is present in standard conventional rectangular entrance cyclones.

Custom designed disengaging hoppers give high efficient separations by creating a void that hosts the bottom section of the descending vortex and allows the particles to disengage from the airstream before it ascends the gas outlet tube.

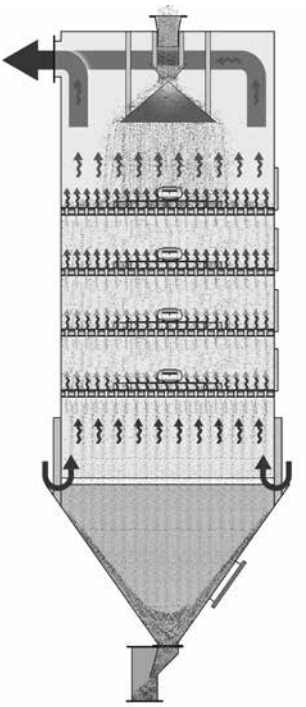


*High efficiency cyclone*

## *Multi-stage fluid bed coolers*

Direct particle cooling and cleaning technologies are designed to process granular feeds. Multi-stage fluid bed coolers have been developed to offer simple practical solutions for cooling and cleaning granular feeds. These coolers are designed to work in conjunction with a dust collector and system fan to create a drop in pressure that draws in atmospheric air.

The feed enters the cooler through an airlock and is then evenly distributed onto the first perforated plate tray. Each tray has specifically designed apertures and is individually vibrated by an electric activator mounted above the plate. The rising airflow passes through the tray apertures and creates a fluidized bed of particles whilst carrying the ultrafine particles away to the dust collector. The fluidized bed dictates the particles residence time before dropping down to the next level plate. The individual particles eventually pass into the collection hopper where they exit the cooler through the sample valve airlock.



*Multi-stage fluid bed cooler*



## *Smart package dust collectors*

To fully support the classification solutions offering, the ancillary equipment requirement must be considered.

To fully support this offering, the ancillary equipment requirement must be considered. The smart package was developed to offer a quality dust collecting solution without unnecessary transportation costs while ensuring quality solutions. Dust collectors tend to be large, bulky pieces of equipment that are expensive to transport due to their significant volume.

The smart package is designed as an easily transportable solution that offers a simple, local manufacturing solution to customers requiring pulse jet dust collectors. The smart package consists of the tube sheet, solenoids, pulse pipes and air manifold. The Smart Package is supplied with Metso's pulse jet dust collector engineering design to ensure successful installation. Smart package designs are available to meet the capacity requirements of the air classifier range and are also suitable for other dust collection duties.

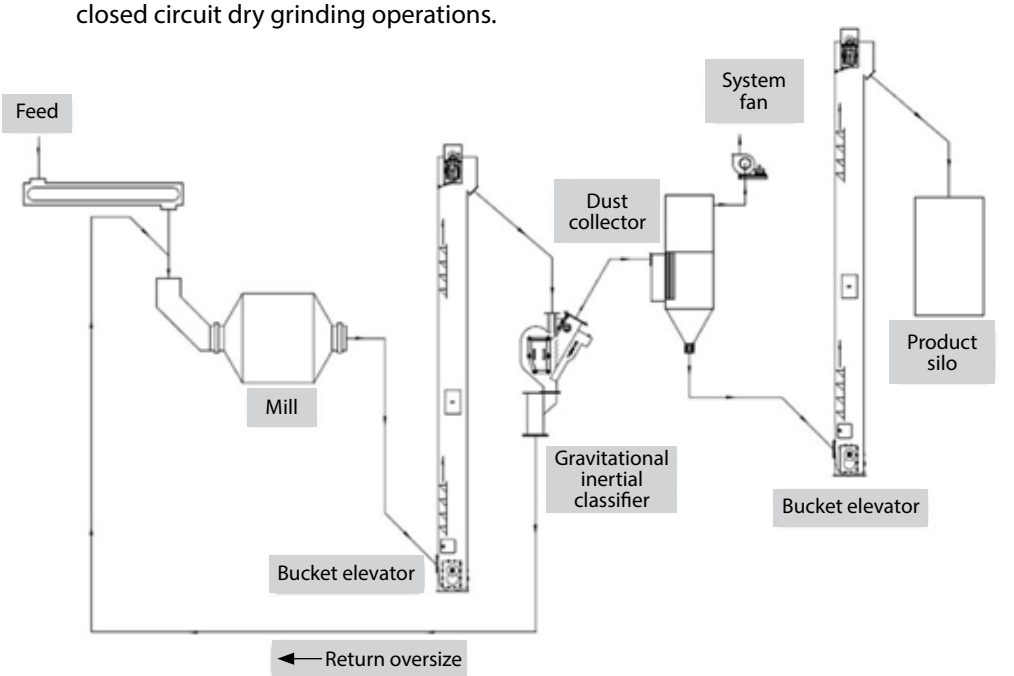
*The smart package dust collector.*

*Close up of the smart package tube sheet, solenoids, pulse pipes and air manifold.*

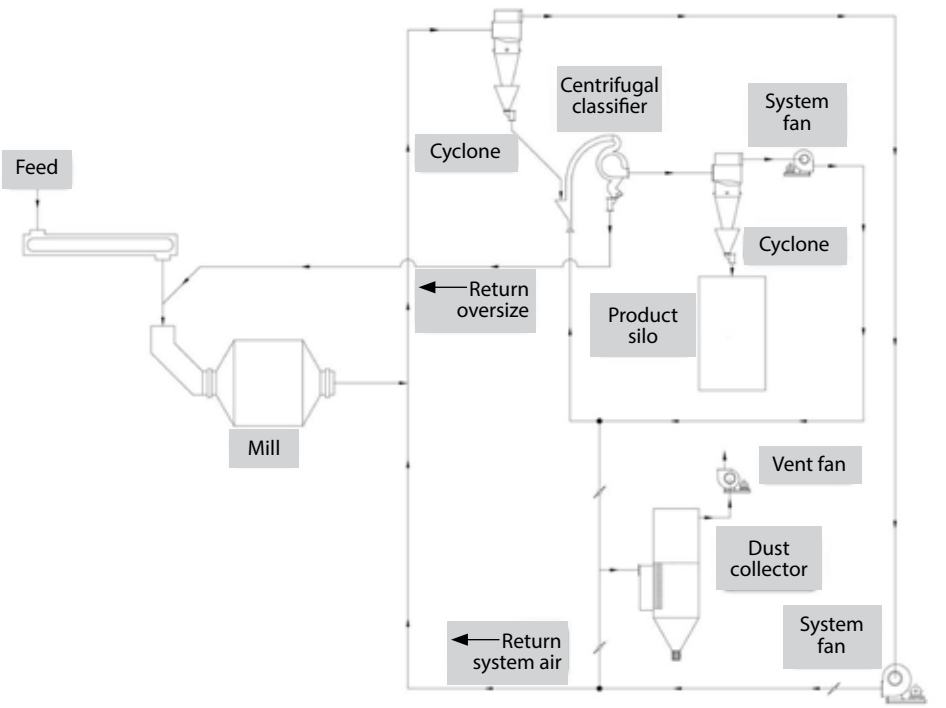
## *Dry Grinding*

There are a wide variety of dry grinding layouts. The design of which are dependent on multiple factors which include: open/closed circuit, tonnage, material flow properties, separation size required, space available, storage and transportation and mill discharge type. Below are a few examples of classifiers in closed circuit dry grinding operations.

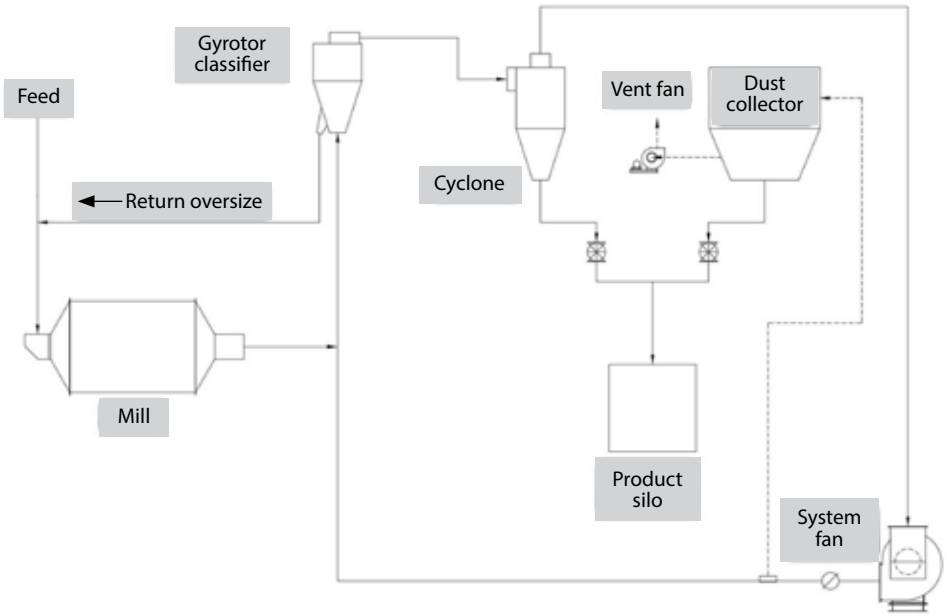




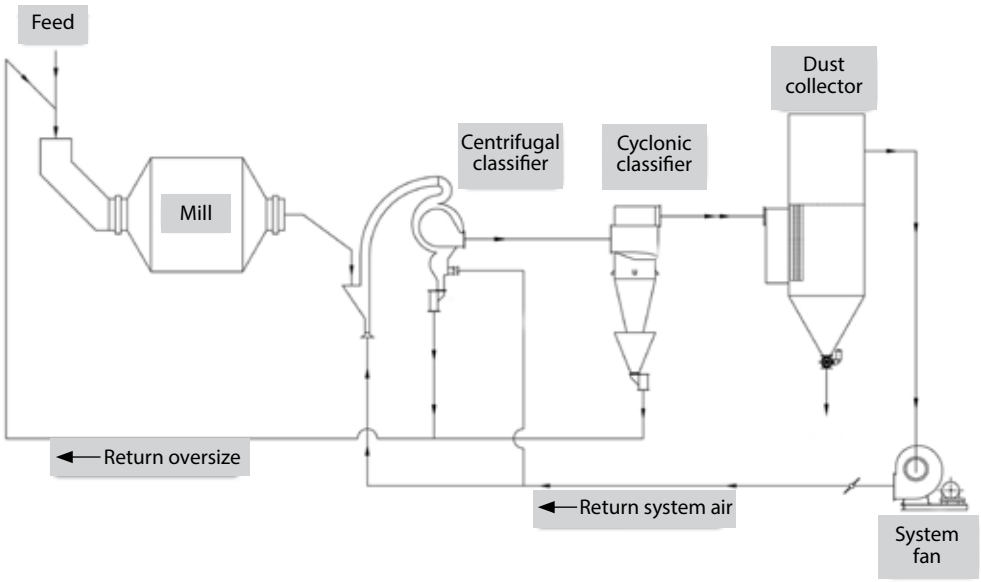

*Grate discharge mill in closed circuit with a Gravitational Inertial classifier producing products in the range of 300/63µm (#50/230)*




*Air swept mill feeding a cyclone disengaging the throughput into Centrifugal classifier with the oversize returning to the mill and producing products in the range of 100/20µm (#140/635)*

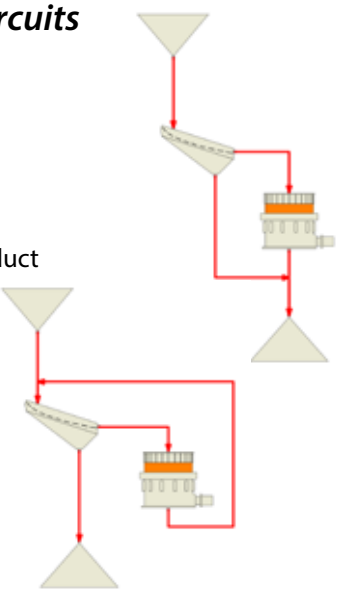



*Grate discharge mill in closed circuit with a Gyrotor Classifier to produce products in the range of 500/45µm (#35/325)*




*Grate discharge mill in closed circuit with both a Centrifugal classifier and a Cyclonic Classifier to produce products in the range of 50/10µm (#270/1250)*

# *Size control in crushing and grinding circuits*



## *Crushing circuits – Open screening*

- Screening ahead of a crusher avoids packing
- Less wear in the crusher
- Higher total capacity
- The screening media is "controlling" the product in two dimensions. No "flaky shortcuts".

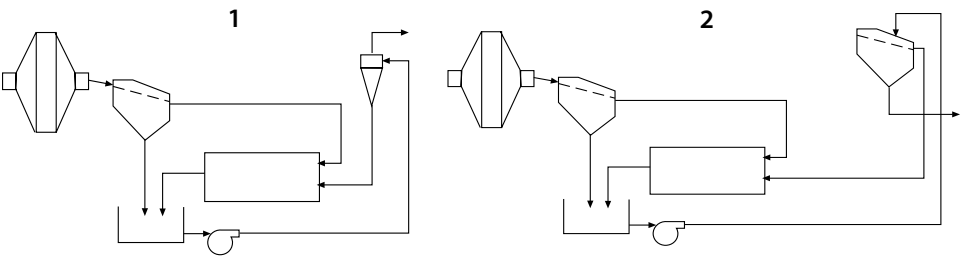
## *Crushing circuits – Closed screening*

- The screens are lowering the capacity
- Calibration of the product is improved
- Better cubical shape
- Higher reduction ratio



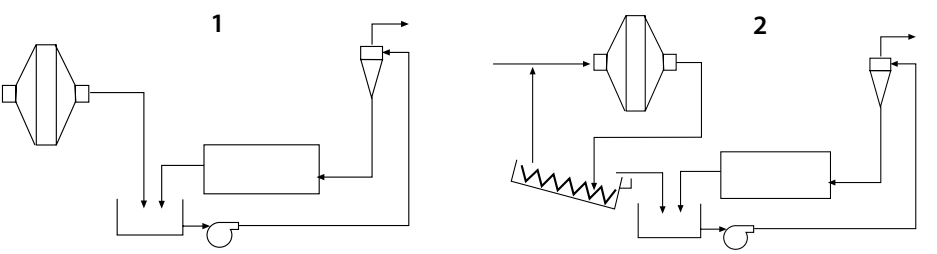
## *Grinding circuits – Screening*

- Used for "trapping critical sizes" in AG - SAG circuits (1)
- Used for taking out size fractions from AG circuits for pebble grinding (1)
- Used in circuits with heavy minerals – avoiding over grinding (fine screening) (2)
- Screens being static (fixed cut point) are not too tolerant to changes in product size, causing variations in circulating loads.
- Mechanical damage or clogging of screening media can disturb operation.




## *Grinding circuits – Classification*

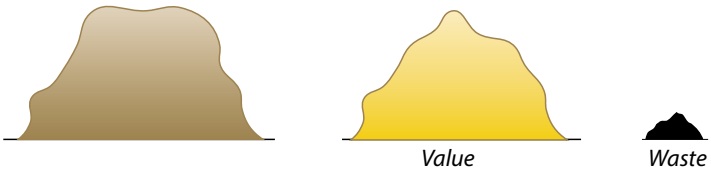
- Classifiers being dynamic (floating cut point) are more tolerant to changes in product size as the cut point is moving with the changes
- Cyclones, being most common, are effective as classifiers at cut points below 300 microns (1)
- Spiral classifiers are effective as classifiers at cut points up to 800 microns. For the coarse fraction solids up to 50mm (2") can be removed by the spiral.
- Spiral classifiers and cyclones can be used complementary if cut point is coarser than 200 microns. (2)



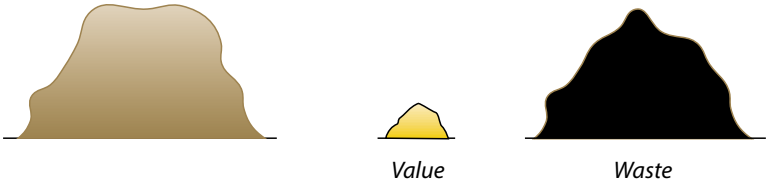
# Enrichment – Introduction

With enrichment we understand the process of improving the mineral or rock value by removing impurities by

- **Washing**, mainly used in the enrichment process of industrial minerals, coal, aggregates, sand and gravel, normally with the products in solid form. (size = 1 mm and coarser)




- **Separation,** mainly used in the enrichment processes of metallic minerals and high value industrial minerals, normally with the products in liberated particle form (size = 1mm and smaller)






# Enrichment – Processes

| Washing by using | Separation by |
|---|---|
| Log washers (not covered) | Gravity separation (wet) |
| Wet screens | Magnetic separation (dry & wet) |
| Aquamator separators (not covered) | Flotation (wet) |
| Tumbling scrubbers | Leaching (wet) |
| Attrition scrubbers | |
| *(all wet processes)* | |

## *Wet screens**

Water spraying can be used to wash materials on a screen regardless of hole size in the screening media. If the hole size is 20 mm or less, water spraying increases the capacity (inversely proportional to the hole size).

Water requirements (typical) $m^3/h$ at low (3-6 bar) and high (above 70 bar) pressure:

| | Low | High |
|---|---|---|
| Sand and gravel | 1.0 | 0.80 |
| Aggregates - hard rock | 0.5 | 0.40 |
| Mining - raw ore | 0.5 | 0.40 |
| Recycling (concrete) | 0.2 | 0.15 |

Capacities typical, see 4:3.

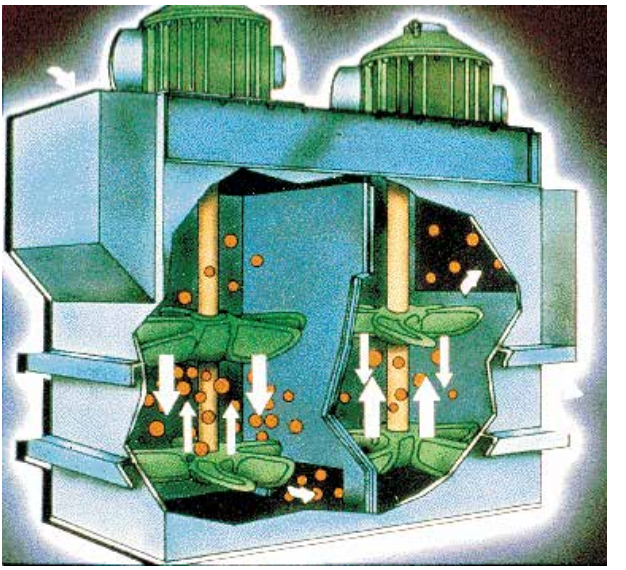
*Not available from Metso.

## *Tumbling scrubber**

If solids of rock, gravel or minerals contain a high and sticky content of clay and dirt that has to be removed, wet screening is normally not effective enough. A medium speed washing drum for scrubbing solids against solids is then the option. The drum is relatively short in relation to its diameter. Water requirements per ton is the same as for wet screening. Typical capacities 8 –120 t/h.

## *Attrition scrubber**

These scrubbers are mainly used for washing of material below 10 mm in size. Very high energy inputs are possibly used for washing of silica sand for glass making and cleaning of foundry sand. The machine is also suitable for clay blunging and lime slaking, see further page 8:31.



* Contact Metso for further information about this product.

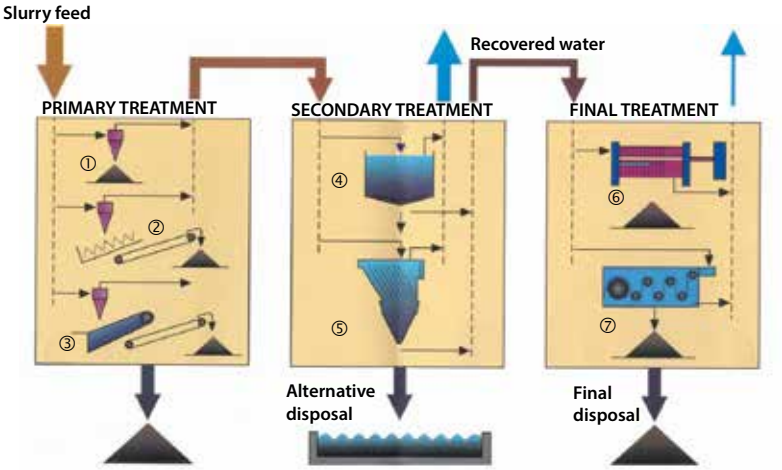
# Wash water treatment

## General

All washing operations are normally consuming a lot of expensive water. Not only costly, but also containing a lot of washing effluents both coarse and fine. Water and effluents that have to be processed partly to recover some value (coarse material and water), partly to protect the environment from damage (sludge fractions).
Most washing operations today must have systems for this treatment.

## Wash water treatment stages

Depending on local conditions and restrictions, one, two or three treatment stages may be required, see below.

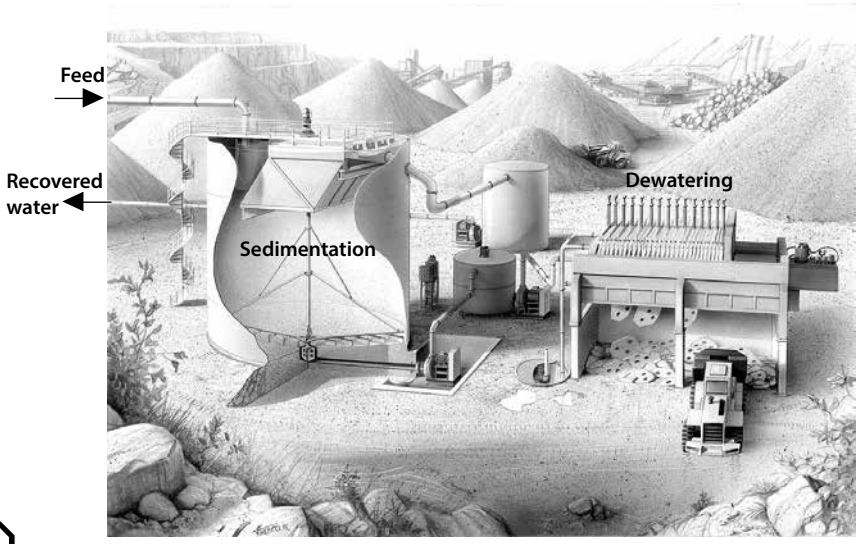



1. Hydrocyclone
2. Dewatering spiral
3. Dewatering screen
4. Conventional clarifier
5. Compact clarifier
6. Simple Pressure filter*
7. Belt press*

*Not covered in this handbook

## Wash water treatment – closed system

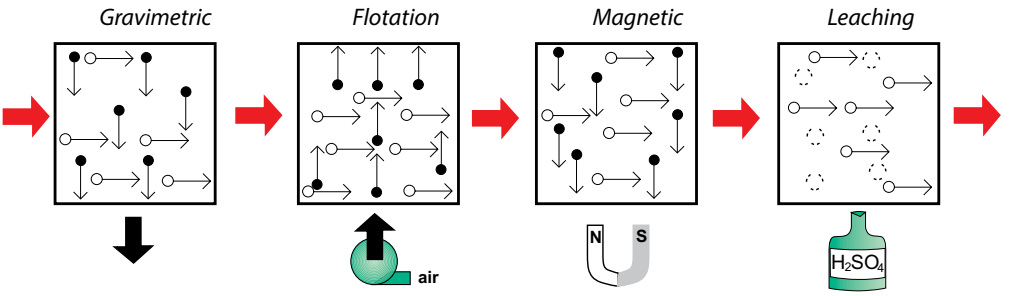
After recovery of coarser material the fines can be treated in a closed system recovering all process water and bringing the fine solids into a transportable form.




For more information see section 6!

## Separation – Introduction

After liberation of all individual minerals in a rock or an ore feed, either by grinding or by natural size reduction (beach sands a.o.) they can be separated individually. Depending on their behavior, different technologies are applied. We will cover the classical methods of separation as per below.




## Separation by gravity



If there is a certain difference in density between two minerals or rock fractions they can be separated by using this difference. Separation by gravity covers two different methods.

- Separation in water (Gravity concentration)
- Separation in a heavy medium (Dense Media Separation, DMS, not covered)

The formula for Separation in water is:

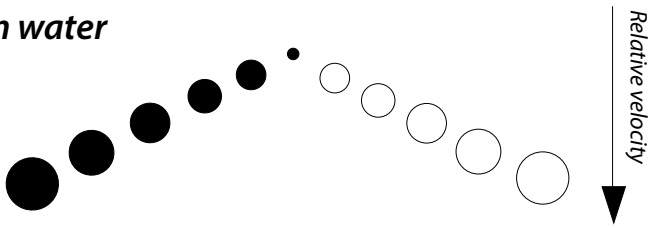
**Density difference (Dd) = (D (heavy mineral)-1) / (D (light mineral)-1)**

The formula for Dense Media Separation is:

**Dd= D (heavy mineral)- D (heavy media) / D (light mineral) - D (heavy media)**

| Value of Dd | Separation | Comments |
|---|---|---|
| + 2.50 | easy | applicable down to 100 micron and lower |
| 1.75 – 2.50 | possible | applicable down to 150 micron |
| 1.50 – 1.75 | difficult | applicable down to 1700 micron |
| 1.25 – 1.50 | very difficult | applicable only for sand & gravel. See washing 5:2 |
| < 1.25 | not possible | |

## Separation in water




| Equipment | Particle size range | Typical applications |
|---|---|---|
| Coal jigs | 40 – 200 mm (1.6 - 8") | Coal |
| Mineral jigs | 75 µm – 6 mm ($3^1/_2$ mesh) | Gold, Chromite, Galena |
| Spirals | 75 µm – 1.0 mm light, (16 mesh)<br>75 µm – 0.5 mm heavy, (32 mesh) | Coal, Beach sands, Iron Cassiterit |
| Shaking tables | 50 µm – 2 mm (9 mesh) | Tin, Copper, Gold, Lead, Zinc, Tungsten |

## *Separation by jigs**

The jig operation consists of two actions. One is the effect of **hindered settling** meaning that a heavier particle will settle faster than a light particle. The other one is the separation process in an **upward flow of water** which will separate the particles by their density.

These two actions are combined in a Jig by slurry pulses generated mechanically or by air.

## *Separation by spiral concentrators**

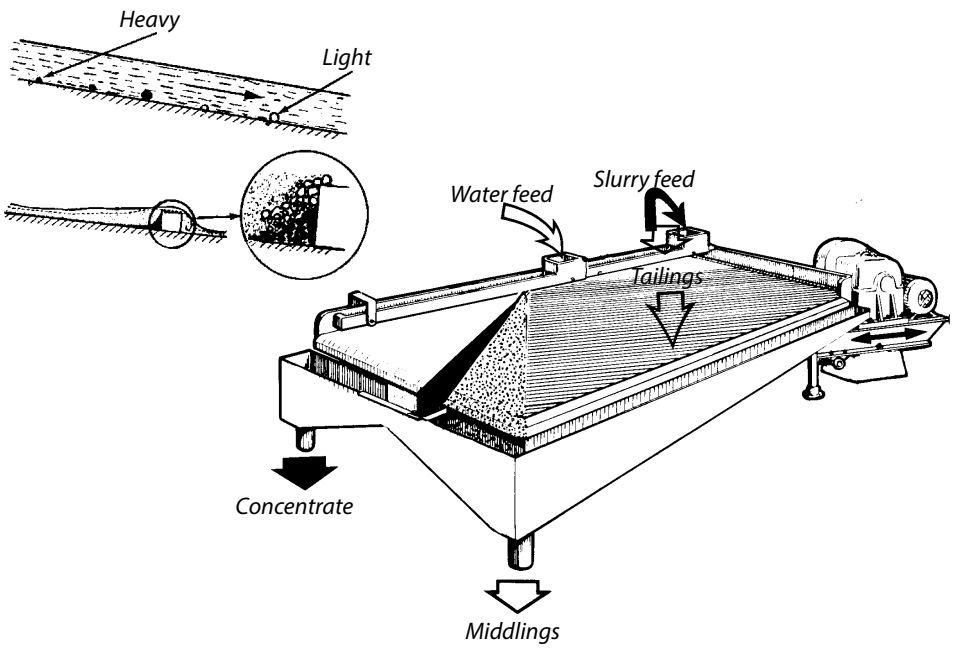
A spiral concentrator uses gravity to separate particles of different densities. It should not be confused with a spiral classifier which usually separates particles of different size, see section 4.

A spiral concentrator consists of one or more helical profiled troughs supported on a central column. As slurry travels down the spiral high and low density particles are stratified and separated with adjustable splitters at the end of the spiral.



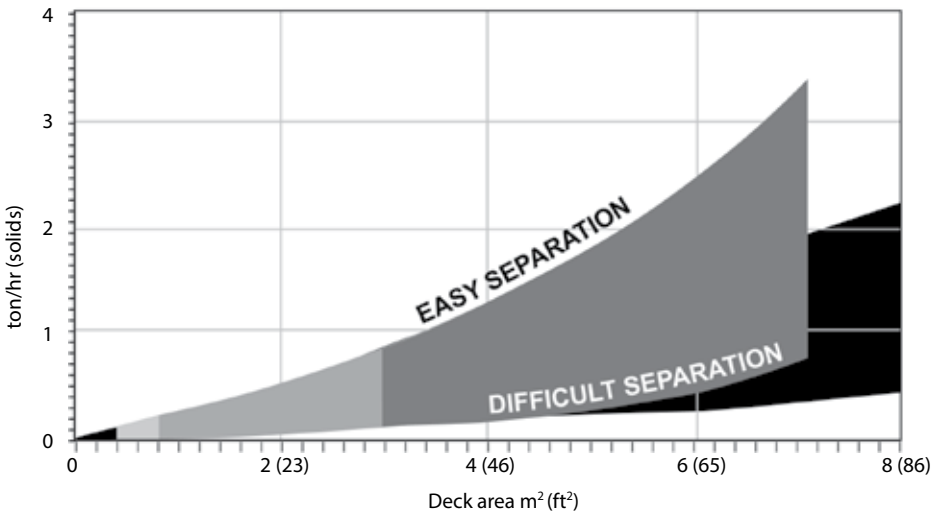
## *Separation by shaking tables**

A cross stream of water transports material over the table to riffles running perpendicular to the direction of feed. Particles build up behind each riffle and stratification occurs with heavier particles sinking to the bottom. The light particles are carried over each riffle to the tailings zone. The shaking action of the tables carries the heavy particles along the back of each riffle to the concentrate discharge.




*Not available from Metso

### *Sizing*

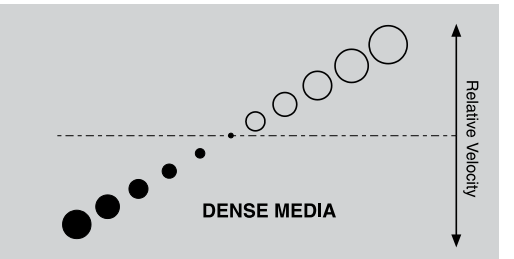





## *Separation in dense media*

Gravity separation utilizes the settling rate of different particles in water to make a separation. Particle size, shape and density all affect the efficiency of the separation.

Dense Media Separation (DMS) takes place in fluid media with a density between that of the light and heavy fractions that are to be separated. The separation is dependent upon density only

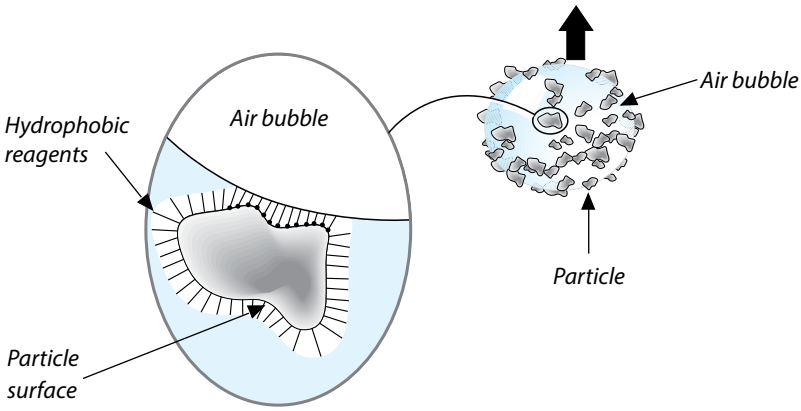



### *DMS – fluid media*

| Media | Density |
|---|---|
| Sand in water | 1.2 – 1.6 |
| Fine (- 50 micron or 270 mesh) Magnetite in water | 1.6 – 2.5 |
| Atomized Ferrosilicon in water | 2.4 – 3.5 |
| "Heavy Liquids" for lab testing | 1.5 – 3.5 |

## *Separation by flotation*

Flotation is a mineral separation process, which takes place in a water-mineral slurry.
The surfaces of selected minerals are made hydrophobic (water-repellent) by conditioning with selective reagents. The hydrophobic particles become attached to air bubbles that are introduced into the pulp and are carried to a froth layer above the slurry thereby being separated from the hydrophilic (wetted) particles.




In addition to the reagents added, the flotation process depends on two main parameters.

- **Retention time** needed for the separation process to occur determines the volume and number of flotation cells required.
- **Agitation** and **aeration** needed for optimum flotation conditions, determine the type of flotation mechanism and the power input required.

### *Size of cells – lengths of banks*

As flotation is based on retention time we have two alternative approaches:

- **Small cells and longer banks**
- **Fewer large cells and shorter banks**

The first alternative is a more conservative approach and is applicable to small and medium tonnage operations. Using more smaller cells in flotation means

- **Reduced short circuiting**
- **Better metallurgical control**
- **Higher recovery**

The second alternative is becoming more accepted for high tonnage operations using large unit volume flotation machines. Modern flotation equipment gives opportunities to use larger cells and shorter circuits.

- **Effective flow pattern minimizes shortcircuiting**
- **Improved on line analyzers will maintain good metallurgical control**
- **Less mechanical maintenance**
- **Less energy input per volume pulp**
- **Lower total cost**

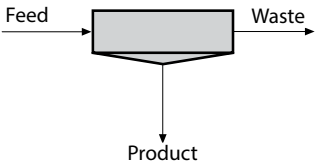
Selection of cell size is made on the basis of the largest individual cell volume that will give the required total flotation volume with an acceptable number of cells per bank. Typical figures for different minerals are given later in this section.

## *Flotation circuit layout*

Flotation circuit designs vary in complexity depending primarily on the type of mineral, degree of liberation of valuable minerals, grade (purity) of the product and the value of the product.

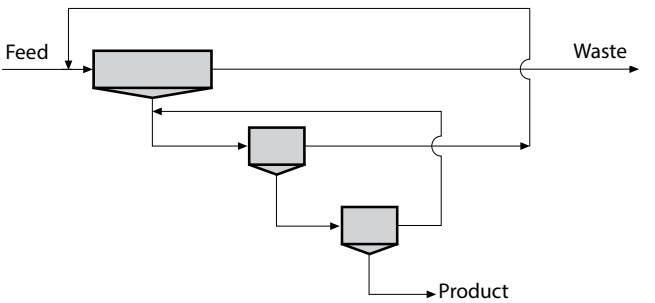
### *Simple circuit (e.g. coal)*

Single stage flotation, with no cleaning of the froth.



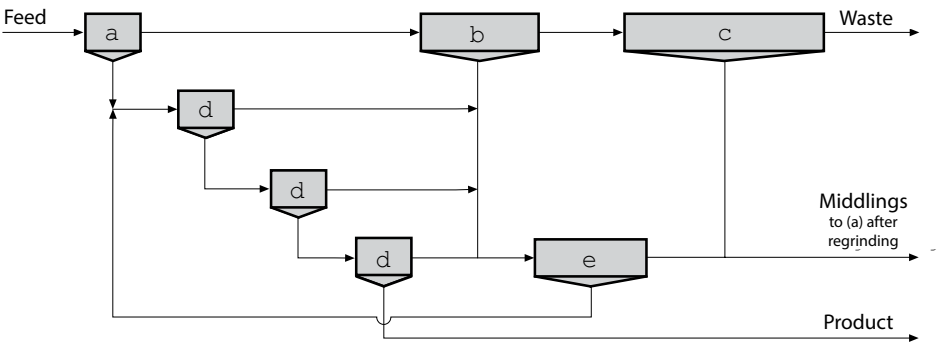

### *Commonly used circuit (e.g. lead)*

Single stage rougher, two stages of cleaning, no regrind.




### *Complex circuit (e.g. copper)*

Two stages roughing (a,b), one stage scavenging (c), three stages cleaning (d), cleaner scavenger (e), regrind.



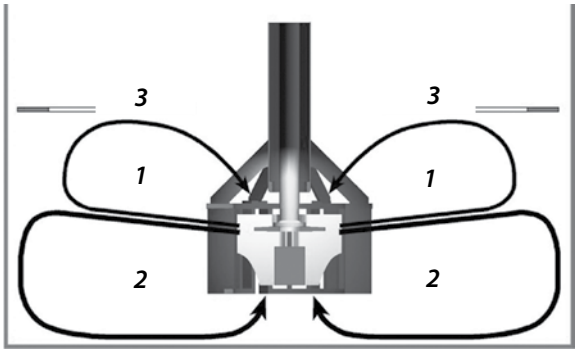

Typically the **first rougher stage** would comprise 10 – 40 % of the total rougher volume and will produce a good grade concentrate with but only medium recovery. **The second rougher stage** comprises 60 – 90 % of the total rougher volume and is designed to maximize recovery.

**The scavenger cells** would have a cell volume equal to the total rougher stage and are included when particularly valuable minerals are being treated or a very high recovery is needed. **Cleaner cells** are used to maximize the grade of the final concentrate. Typical cleaner retention time is 65 – 75% of that for rougher flotation and will be at a lower percent solids. Less cells per bank than for rougher duties can be used.

## *Reactor cell flotation system (RCS)*

The RCS™ (Reactor Cell System) flotation machine utilizes the patent protected DV™ (Deep Vane) Mechanism. Flow pattern characteristics are:

- Powerful radial slurry flow patterns to tank wall (1).
- Primary return flow to underside of impeller (2).
- Secondary top recirculation (3).




Flotation enhanced due to:

- Maximum particle-bubble contacts within the mechanism and tank.
- Effective solids suspension during operation and re-suspension after shutdown.
- Effective air dispersion throughout the complete cell volume.

### *Features of the RCS™ (Reactor Cell System):*

- Active lower zone for optimum solid suspension and particle – bubble contact.
- Upper zone with reduced turbulence to prevent particle – bubble separation.
- Quiescent cell surface to minimize particle re-entrainment.
- Circular tank with low level slurry entry and exit to minimize slurry short circuiting.
- Cell size 0.8 – 300 $m^3$ (28 – 10600 $ft^3$)
- V-V drive up to 70 $m^3$. Gearbox drive for 100 $m^3$ and above. (V-V drive for larger volume cells optional)
- Automatic level control by dart valves.
- Separate source of low pressure air.
- Double internal cross-flow froth launders or internal peripheral launders with central crowder.
- Application: The majority of mineral flotation duties.

See data sheet 5:14.

## *Reactor cell system (RCS) – Sizing, metric*

Selection of the size and number of cells for each stage of the flotation circuit (roughing, cleaning etc) is made by a three step calculation.

### *1. Determination of total flotation cell volume*

Total flotation cell volume required can be calculated from the formula:

$$\mathbf{Vf} = \frac{\mathbf{Q \times Tr \times S}}{\mathbf{60 \times Ca}}$$

**Vf** = Total flotation volume required ($m^3$)

**Q** = Feed flow rate $m^3$/hr

**Tr** = Flotation retention time (minutes). Typical figures for different minerals are given overleaf, alternatively the retention time may be specified by the customer or be determined from testwork.

**S** = Scale up factor dependent upon source of flotation retention time date (above)

Tr specified by customer S = 1.0

Tr taken from typical industrial data S = 1.0

Tr taken from continuous Pilot Plant test S = 1.0

Tr taken from laboratory scale test work S = 1.6 – 2.6

**Ca** = Aeration factor to account for air in pulp. 0,85 unless otherwise specified.

### *2. Select the number of cells per bank*

The table overleaf shows typical amount of cells per bank for common mineral flotation duties. Divide Vf calculated above by number of cells selected to calculate volume ($m^3$) per cell. Check that Q is in flow rate range for cell size selected. Reselect if necessary.

### *3. Select the bank arrangement*

To ensure necessary hydraulic head to allow slurry to flow along the bank intermediate boxes may be required. Maximum numbers of cells in a section between intermediate or discharge boxes are given overleaf. Each bank will also need a feed box and a discharge box.

Typical bank designation is F-4-I-3-D, i.e. Feed box, four cells, intermediate box, three cells, discharge box.

### *Reactor cell system flotation sizing*

Selection data for rougher flotation duties are as follows:

| Mineral | % solids in feed | Retention time min (normal) | No. of cells/bank |
|---|---|---|---|
| **Barite** | 30 – 40 | 8 – 10 | 6 – 8 |
| **Copper** | 32 – 42 | 13 – 16 | 8 – 12 |
| **Fluorspar** | 25 – 32 | 8 – 10 | 6 – 8 |
| **Feldspar** | 25 – 35 | 8 – 10 | 6 – 8 |
| **Lead** | 25 – 35 | 6 – 8 | 6 – 8 |
| **Molybdenum** | 35 – 45 | 14 – 20 | 10 – 14 |
| **Nickel** | 28 – 32 | 10 – 14 | 8 – 14 |
| **Phosphate** | 30 – 35 | 4 – 6 | 4 – 5 |
| **Potash** | 25 – 35 | 4 – 6 | 4 – 6 |
| **Tungsten** | 25 – 32 | 8 – 12 | 7 – 10 |
| **Zinc** | 25 – 32 | 8 – 12 | 6 – 8 |
| **Silica (iron ore)** | 40 – 50 | 8 – 10 | 8 – 10 |
| **Silica (phosphate)** | 30 – 35 | 4 – 6 | 4 – 6 |
| **Sand (impurity)** | 30 – 40 | 7 – 9 | 6 – 8 |
| **Coal** | 4 – 12 | 4 – 6 | 4 – 5 |
| **Effluents** | as received | 6 – 12 | 4 – 6 |

For cleaning applications use 60% of the rougher percent solids. Required retention time for cleaning is approx. 65% of rougher retention time.

Selection data for reactor cell system (metric) are as follows:

| Model | Volume ($m^3$) | Maximum bank feed rate ($m^3/h$) | Maximum cells per section (1) |
|---|---|---|---|
| **RCS 0,8** | 0,8 | 25 | 4 |
| **RCS 3** | 3,0 | 240 | 4/5 |
| **RCS 5** | 5,0 | 320 | 4/5 |
| **RCS 10** | 10,0 | 540 | 4 |
| **RCS 15** | 15,0 | 730 | 4 |
| **RCS 20** | 20,0 | 870 | 4 |
| **RCS 30** | 30,0 | 1120 | 3 |
| **RCS 40** | 40,0 | 1360 | 3 |
| **RCS 50** | 50,0 | 1650 | 3 |
| **RCS 70** | 70,0 | 2040 | 2 |
| **RCS 100** | 100,0 | 2550 | 2 |
| **RCS 130** | 130,0 | 3050 | 2 |
| **RCS 160** | 160,0 | 3450 | 1 |
| **RCS 200** | 200,0 | 3990 | 1 |
| **RCS 300** | 300,0 | 6500 | 1 |

*(1) Number of cells on same level between connecting boxes*

## *Reactor cell system flotation – Example calculation*

**Requirement:**

Single rougher bank. Copper flotation.

Feed pulp flow rate 1400 $m^3$/h (6160 USGPM).

Retention time 16 minutes, determined by continuous pilot plant test.

**1. Determination of total flotation cell volume**

$$Vf = \frac{Q \times Tr \times S}{60 \times Ca} = \frac{1400 \times 16 \times 1}{60 \times 0.85} = 439\ m^3 \text{ total bank volume}$$

**2. Select the number of cells in bank**

Minimum cell size to handle 1400 $m^3$/hr is RCS 50 (Maximum 1650 $m^3$/hr).

439 / 50 = 8.78 cells. Normal range for copper is 8 - 12 cells, so this is a valid selection. If this was not the case choose the next cell size up or down as appropriate.

9 x RCS 50 cells required. Total volume 9 x 50 = 450 $m^3$.

**3. Select the bank arrangement**

For RCS 50 the maximum amount of cells in one section is 3. So to have 9 cells choose bank arrangement.

**RCS 50 F-3-I-3-I-3-D**

## *RCS specifications*

| | Standard | Cell volume (2) | | Connected motor (3) | | Air requirements (4) | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model** | **Drive (1)** | **$m^3$** | **$ft^3$** | **kW** | **HP** | **$Am^3$/min** | **kPag** | **Acfm** | **psig** |
| **RCS 0,8** | *For specifications please contact your local Metso sales office* | | | | | | | | |
| **RCS 3** | VB | 3 | 105 | 11 | 15 | 2 | 17 | 70 | 2,5 |
| **RCS 5** | VB | 5 | 175 | 15 | 20 | 3 | 19 | 110 | 2,8 |
| **RCS 10** | VB | 10 | 355 | 22 | 30 | 4 | 22 | 140 | 3,2 |
| **RCS 15** | VB | 15 | 530 | 30 | 40 | 6 | 25 | 210 | 3,6 |
| **RCS 20** | VB | 20 | 705 | 37 | 50 | 7 | 27 | 250 | 3,9 |
| **RCS 30** | VB | 30 | 1060 | 45 | 60 | 9 | 31 | 320 | 4,5 |
| **RCS 40** | VB | 40 | 1410 | 55 | 75 | 10 | 34 | 350 | 4,9 |
| **RCS 50** | VB | 50 | 1765 | 75 | 100 | 12 | 38 | 420 | 5,5 |
| **RCS 70** | VB | 70 | 2470 | 90 | 125 | 15 | 41 | 530 | 5,9 |
| **RCS 100** | VB/GB | 100 | 3530 | 110 | 150 | 19 | 47 | 670 | 6,8 |
| **RCS 130** | VB/GB | 130 | 4590 | 132 | 200 | 23 | 51 | 810 | 7,4 |
| **RCS 160** | GB | 160 | 5650 | 160 | 200/250 | 25 | 55 | 880 | 8,0 |
| **RCS 200** | GB | 200 | 7060 | 200 | 250 | 30 | 59 | 1060 | 8,6 |
| **RCS 300** | *For specifications please contact your local Metso sales office* | | | | | | | | |

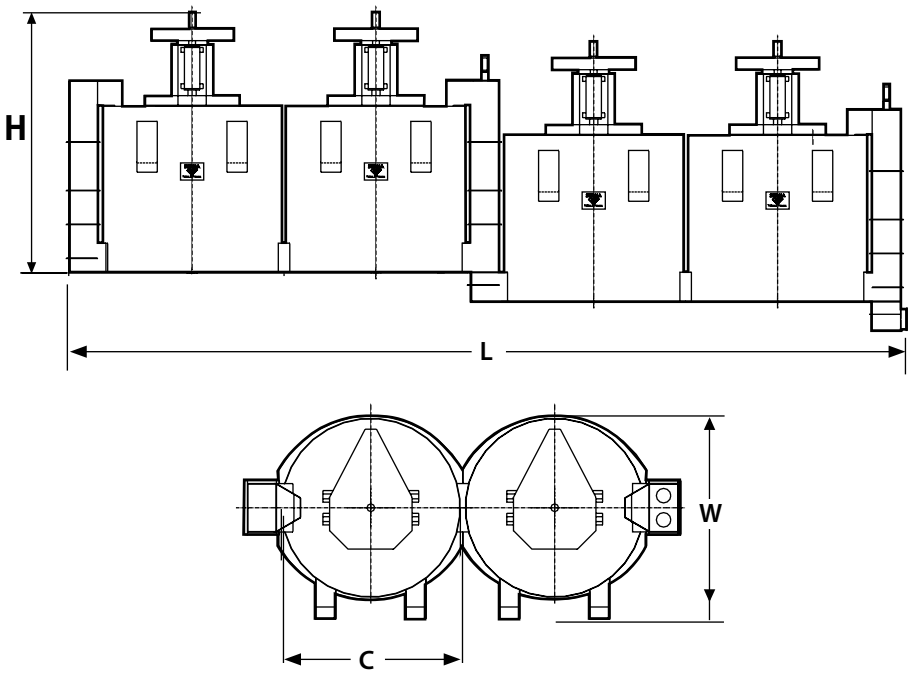
*(1) VB - spindle bearing with V-belt drive GB - gearbox with v-belt drive*

*(2) Active flotation volume*

*(3) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso*

*(4) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso*
*Air requirement is at flotation mechanism, pressure losses from blower to flotation bank should be considered when specifying blower*

## *Flotation machine – RCS*






| Model | H (1) mm (inch) | L (2) mm (inch) | W mm (inch) | C mm (inch) | Bank weight (2) tonnes (s tons) |
|---|---|---|---|---|---|
| **RCS 0,8** | 1 790 (70) | 5 550 (219) | 1 320 (52) | 1 100 (43) | 2,73 (3,01) |
| **RCS 3** | 2 790 (110) | 8 250 (325) | 1 900 (75) | 1 700 (67) | 8,4 (9,26) |
| **RCS 5** | 3020 (119) | 9850 (388) | 2230 (88) | 2000 (79) | 10.53 (11.58) |
| **RCS 10** | 3610 (142) | 12250 (482) | 2850 (112) | 2600 (102) | 17.38 (19.12) |
| **RCS 15** | 3990 (157) | 14250 (561) | 3320 (131) | 3000 (118) | 22.97 (25.27) |
| **RCS 20** | 4610 (181) | 15250 (600) | 3680 (145) | 3250 (128) | 26.25 (28.88) |
| **RCS 30** | 5375 (212) | 17350 (683) | 4150 (163) | 3700 (146) | 36.50 (40.15) |
| **RCS 40** | 5780 (226) | 19200 (756) | 4410 (174) | 4100 (161) | 51.04 (56.14) |
| **RCS 50** | 6100 (240) | 20900 (823) | 4870 (192) | 4500 (177) | 56.95 (62.65) |
| **RCS 70** | 6690 (263) | 23600 (929) | 5450 (215) | 5000 (197) | 71.00 (78.10) |
| **RCS 100** | 6510 (256) | 26400 (1039) | 6100 (240) | 5600 (220) | 92.28 (101.51) |
| **RCS 130** | 6875 (271) | 29050 (1144) | 6650 (262) | 6100 (240) | 123.82 (136.2) |
| **RCS 160** | 7495 (295) | 30650 (1207) | 7100 (280) | 6500 (256) | 145.49 (160.00) |
| **RCS 200** | 8050 (317) | 33050 (1301) | 7600 (299) | 7000 (276) | 174.10 (191.40) |
| **RCS 300** | *For specifications please contact your local Metso sales office* | | | | |

*(1) RCS 3 to RCS 70 v-drive, RCS 100 to RCS 200 gearbox drive*

*(2) 4-cell bank arranged F-2-I-2-D, empty*

# DR Flotation cell system

The Reactor Cell System Flotation Machine is the preferred choice for many mineral flotation applications. The DR design may be specified for certain applications, particularly where de-slimed coarse particles have to be handled such as in glass and potash processing. Features of the DR design are as follows:

## Flotation system DR – Design

- Open flow tank with intermediate and discharge boxes
- Near bottom located impeller/ diffuser
- Separate source of low pressure air
- Level control by weir or dart valves (automatic as option)
- Recirculation well
- Reversible impeller direction of rotation
- Max cell size 14 $m^3$

See data sheet 5:16-17.

## DR – Specifications

| Model | Cell volume (1) $m^3$ | Cell volume (1) $ft^3$ | Connected motor (2) kW | Connected motor (2) HP | Air requirements (3) $Am^3$/min | Air requirements (3) kPag | Air requirements (3) Acfm | Air requirements (3) psig |
|---|---|---|---|---|---|---|---|---|
| **DR 15** | 0,34 | 12 | 2,2 | 3,0 | 0,4 | 7 | 15 | 1.0 |
| **DR 18Sp** | 0,71 | 25 | 4,0 | 5,0 | 0,7 | 9 | 25 | 1.3 |
| **DR 24** | 1,42 | 50 | 5,5 | 7,5 | 1,3 | 10 | 45 | 1.6 |
| **DR 100** | 2,83 | 100 | 11,0 | 15,0 | 2,3 | 10 | 80 | 1.6 |
| **DR 180** | 5,10 | 180 | 15,0 | 20,0 | 3,1 | 14 | 110 | 2.0 |
| **DR 300** | 8,50 | 300 | 22,0 | 30,0 | 4,5 | 18 | 160 | 2.6 |
| **DR 500** | 14,16 | 500 | 30,0 | 40,0 | 6,5 | 18 | 230 | 2.6 |

*(1) Active flotation volume*

*(2) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso*

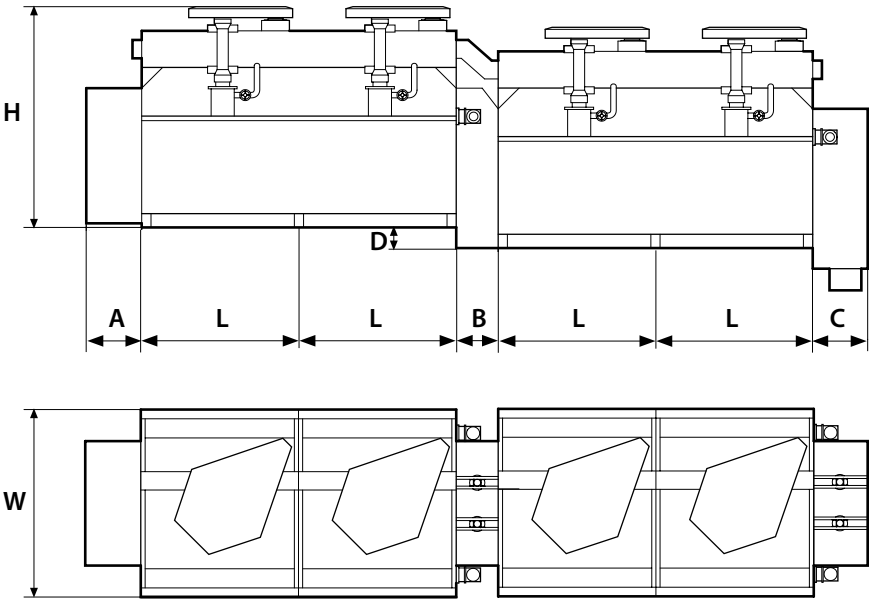
*(3) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso Air requirement is at flotation bank air header, pressure losses from blower to flotation bank should be considered when specifying blower*

## DR – Cell volumes and hydraulic capacities

| Model | Maximum Bank Feed Rate $m^3/h$ | Maximum Bank Feed Rate USGPM | Maximum cells per bank section (1) |
|---|---|---|---|
| **DR15** | 25 | 110 | 15 |
| **DR18 sp** | 55 | 240 | 12 |
| **DR24** | 110 | 485 | 9 |
| **DR100** | 215 | 945 | 7 |
| **DR180** | 415 | 1 825 | 6 |
| **DR300** | 580 | 2 550 | 5 |
| **DR500** | 760 | 3 345 | 4 |

*(1) Number of cells on same level between connecting boxes*

## *Flotation machine – DR, Metric*



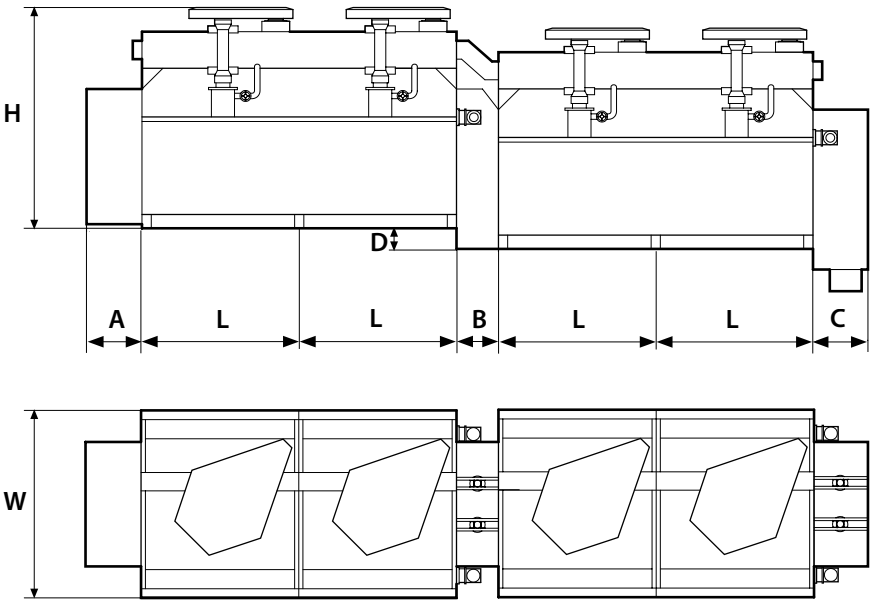



| Model (1) | Volume/ cell $m^3$ | Cells/ unit (2) | A mm | B mm | C mm | D (min) mm | L (5) mm | W mm | H mm | Motor size (3) kW | Motor size (4) kW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **8** | 0.09 | | 152 | 279 | 279 | 152 | 483 | 406 | 1118 | 1.1 | 2.2 |
| **15** | 0.28 | 15 | 203 | 381 | 381 | 152 | 711 | 610 | 1626 | 3.0 | 5.0 |
| **18** | 0.71 | 12 | 305 | 457 | 457 | 203 | 914 | 813 | 1829 | 5.0 | 10.0 |
| **24** | 1.40 | 9 | 305 | 457 | 457 | 203 | 1219 | 1092 | 2362 | 5.5 | 15.0 |
| **100** | 2.80 | 7 | 457 | 457 | 457 | 203 | 1575 | 1575 | 2718 | 7.5-11 | - |
| **180** | 5.10 | 6 | 508 | 610 | 762 | 254 | 1829 | 1829 | 2946 | 11-15 | - |
| **300** | 8.90 | 5 | 610 | 762 | 914 | 305 | 2235 | 2235 | 3302 | 18-22 | - |
| **500** | 14.20 | 4 | 762 | 914 | 914 | 305 | 2692 | 2692 | 3404 | 25-30 | - |
| **1500** | 36.10 | 3 | 1219 | 1067 | 1372 | 406 | 4267 | 4267 | 4369 | 55 | - |

*(1) From size 18 and above Single or Double side overflow.*
*(2) Number of cells without Intermediate box.*
*(3) Single cell drive.*
*(4) Dual cell drive.*
*(5) Length per cell.*

For dimensions in inch, see next page

# *Flotation machine – DR, US*






| Model (1) | Volume/ cell $ft^3$ | Cells/ unit (2) | A inch | B inch | C incn | D (min) inch | L (5) inch | W inch | H inch | Motor size (3) hp | Motor size (4) hp |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **8** | 3 | | 6 | 11 | 11 | 6 | 19 | 16 | 44 | 1 ½ | 3 |
| **15** | 12 | 15 | 8 | 15 | 15 | 6 | 28 | 24 | 64 | 4 | 7 |
| **18** | 25 | 12 | 12 | 18 | 18 | 8 | 36 | 32 | 72 | 6½ | 14 |
| **24** | 50 | 9 | 12 | 18 | 18 | 8 | 48 | 43 | 93 | 7 | 20 |
| **100** | 100 | 7 | 18 | 18 | 18 | 8 | 62 | 62 | 107 | 10-15 | - |
| **180** | 180 | 6 | 20 | 24 | 30 | 10 | 72 | 72 | 116 | 15-20 | - |
| **300** | 300 | 5 | 24 | 30 | 36 | 12 | 88 | 88 | 130 | 25-30 | - |
| **500** | 500 | 4 | 30 | 36 | 36 | 12 | 106 | 106 | 134 | 30-40 | - |
| **1500** | 1500 | 3 | 48 | 42 | 54 | 16 | 168 | 168 | 172 | 74 | - |

*(1) From size 18 and above Single or Double side overflow.*
*(2) Number of cells without Intermediate box.*
*(3) Single cell drive.*
*(4) Dual cell drive.*
*(5) Length per cell.*

For metric dimensions see previous page

## *Column flotation cells*

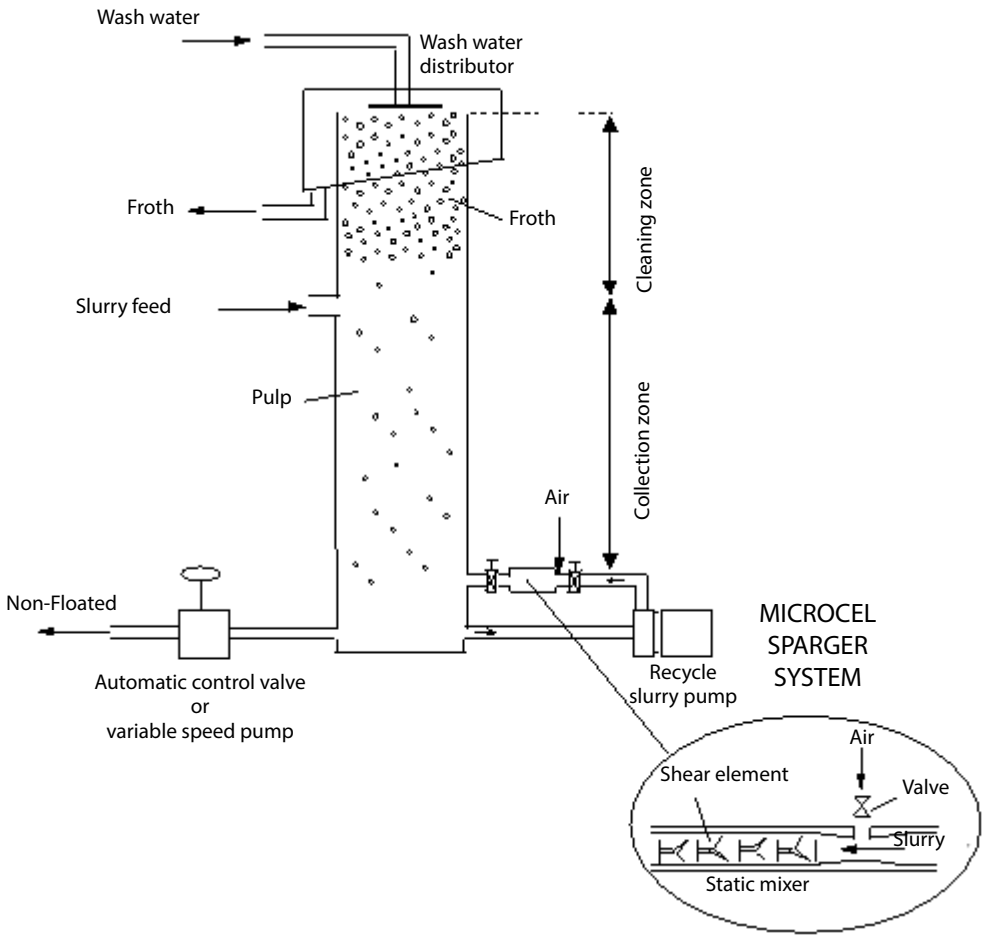
Column flotation cells, like mechanical cells, are used to perform mineral separations. Column cells do not use mechanical agitation (impellers). Instead, mixing is achieved by the turbulence provided by the rising bubbles. Columns are mostly used to produce final grade concentrates because they are capable of high selectivity. Other features which distinguish them from mechanical cells are their shape, bubble generation system and the use of wash water. An optimum flotation circuit is a combination of mechanical cells and column cells.

In specific applications such as cleaning duties or handling of very fine particles column flotation will offer the following advantages:

- Improved metallurgical performance
- Low energy consumption
- Less floor area
- Less maintenance
- Improved control



### *Schematic of Microcel flotation column*



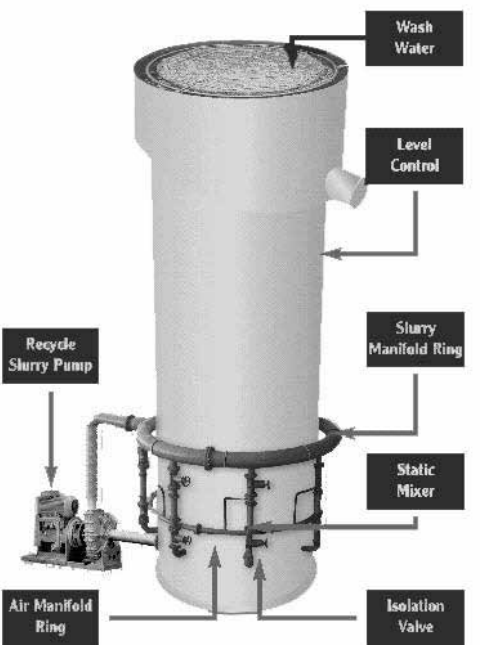
## *Column flotation – Microcel sparger features*

The Microcel sparger consists of inline **static mixers** and **a recycle slurry pump**. Tailings

slurry is pumped from the base of the column through the static mixers where air and slurry are mixed together under high shear conditions to create the bubble dispersion. As the air/ slurry mixture passes through the stationary blades located inside the mixer the air is sheared into very small bubbles by the intense agitation. The bubble suspension is introduced near the column base.

Slurry **level control** is achieved by using ultrasonic sensor or differential pressure transmitters to automatically adjust the tailings flow control valve.

**Wash water** addition improves grade by removing mechanically entrained particles.




### *Selection*

For detailed column design – contact your support center supplier. A preliminary indication of design parameters can be derived from the following notes.

- Column designs available up to 6 m in diameter. Flotation column cells are custom designed for each application.
- Typical superficial slurry velocity: 0.2 – 1.2 cm/s
- Typical froth carrying capacity: 2 t/h/$m^2$
- Typical superficial air velocity: 1.5 – 1.8 cm/s
- Height of column selected to give slurry retention time in range 10 – 20 min.
- Typical superficial wash water velocity: 0.05 – 0.2 cm/s

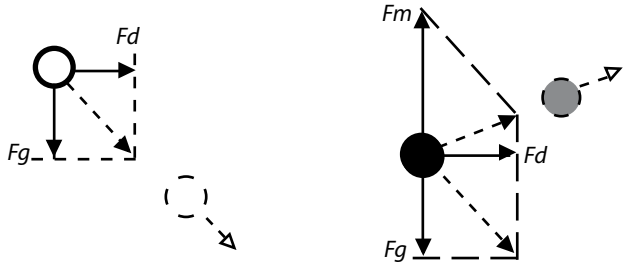
### *Applications*

Applications for flotation columns include:

- Sulfides
- Iron ore
- Phosphate
- Coal
- Industrial minerals
- Potash

## *Magnetic separation – Introduction*

By creating an environment comprimizing a **magnetic force** (Fm), a **gravitational force** (Fg) and a **drag force** (Fd) magnetic particles can be separated from non-magnetic particles by **Magnetic Separation.**




### *Magnetic separation - Magnetic attraction force (Fm)*

Fm = V x $\chi$ x H x grad H

V = **particle volume** (determined by process)

$\chi$ = **magnetic susceptibility** (see table below)

H = **magnetic field** (created by the magnet system design) in mT (milliTesla) or kG (kiloGauss) 1 kG = 100 mT = 0.1 T

grad H = **Magnetic field gradient** (created by the magnet system design) in mT/m

***Magnetic field and magnetic gradient are equally important factors for creating the magnet attraction force.***

| Mineral | Magnetic susceptibility ($X_m$ x $10^6$ emu/g) | |
|---|---|---|
| Magnetite | 20 000 – 80 000 | Ferromagnetic (strong magnetic) |
| Pyrrhotite | 1 500 – 6 100 | |
| Hematite | 172 – 290 | Paramagnetic (weakly magnetic) |
| Ilmenite | 113 – 271 | |
| Siderite | 56 – 64 | |
| Chromite | 53 – 125 | |
| Biotite | 23 – 80 | |
| Goethite | 21 – 25 | |
| Monazite | 18.9 | |
| Malachite | 8.5 – 15.0 | |
| Bornite | 8.0 – 14.0 | |
| Rutile | 2.0 | |
| Pyrite | 0.21 | |
| Cassiterite | – 0.08 | Diamagnetic (repelling) |
| Fluorite | – 0.285 | |
| Galena | – 0.35 | |
| Calcite | – 0.377 | |
| Quartz | – 0.46 | |
| Gypsum | – 1.0 | |
| Sphalerite | – 1.2 | |
| Apatite | – 2.64 | |

### *Magnetic separation – Competing forces*

- **Gravitational force** ($F_g$) is determined by particle size and density.
- **Drag force** (hydrodynamic, aerodynamic), $F_d$, is determined by particle size, shape, fluid density, viscosity, turbidity and velocity.
- **Centripetal force** ($F_c$).
- **Adhesion**
- **Electrostatic forces etc.**

## *Magnetic separation – Methods*

### *Low Intensity Magnetic Separation, LIMS*

- Dry and wet methods
- For separation of ferromagnetic particles
- Magnetic field intensity up to 300 mT
- Particle sizes up to 300 mm

### *Medium Intensity Magnetic Separation, MIMS**

- Dry and wet methods
- For separation of ferromagnetic particles
- Magnetic field intensity up to 800 mT
- Particle sizes up to 300 mm

*N B At present MIMS is not available from Metso. When MIMS becomes available the above data may alter.

### *High Gradient Magnetic Separation, HGMS*

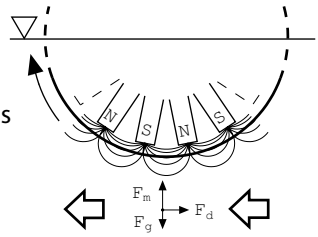
- Cyclic and continuous methods
- For separation of paramagnetic particles
- Magnetic field intensity up to 2 T
- Limited to processing of particles finer than about 1 mm

## Magnetic separation – Separator types

### Wet LIMS = Low intensity magnetic separators

- Wet separation of ferromagnetic particles
- Magnetic field in separation zone * up to 1.2 kGauss

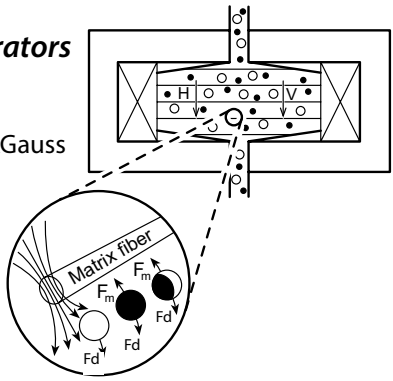
* approx. 50 mm (2 inches) from drum surface




### Wet HGMS = High gradient magnetic separators

- Wet separation of paramagnetic particles
- Magnetic field in separation zone* = 2 – 20 kGauss

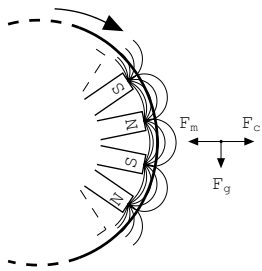
* on matrix surface




### Dry LIMS = Low intensity magnetic separators

- Dry separation of ferromagnetic particles
- Magnetic field in* separation zone up to 1.2 kGauss

* approx. 15 mm (5/8 inch) from magnet surface




## Magnetic separation equipment

All LIMS models, wet and dry versions, comprise magnetic drum assemblies mounted in either tanks or dust housings. The magnetic assembly comprises a stationary magnetic array installed in a rotating outer drum. The drum rotation speed and direction are selected for the application in question.

Generally coarse material is processed by dry LIMS and fine material by either dry or wet LIMS. The upper particle size limit for wet processing is about 8 mm but with special arrangements coarser material can be processed by wet methods.

## *Dry LIMS – Belt drum separator, BS*

The belt drum separator, BS, is generally used in iron ore beneficiation to either produce coarse final products or for reducing feed mass to following process stages. It is also used for steel slag and pyrite cinder treatment.

**Features**

- Magnetic system with three different pole pitches with alternating polarity (models BSA)
- Special pole design with fixed polarity in rotating direction for coarse material, (model BSS)
- For low to high Fe grade feed
- Belt speeds up to 3 m/s (20 ft/min)
- Belt feed for even distribution of feed material
- Adjustable product splitter for product quality control
- Coarse particle tolerant, up to 250 - 300 mm
- Basically used in primary stages
- Can be arranged in single stage or multistage processing
- Very large unit capacity

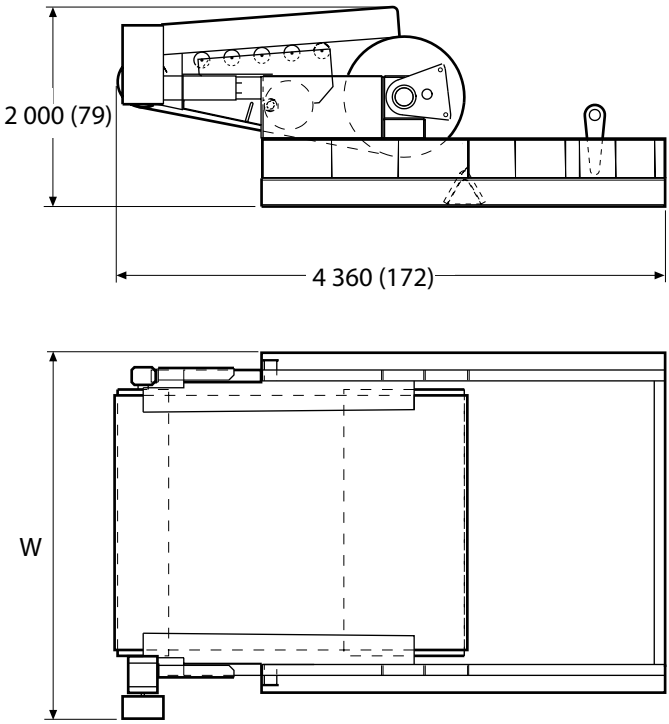


### *Recommended pole pitch and capacity ranges*

| Model | Pole pitch (pp) | Feed size mm | Feed size inch | Capacity t/h / m, st/h/ft, up to |
|---|---|---|---|---|
| BSA1200-112 | 112 | 5 – 75 | 3/16 – 3 | 150, 50 |
| BSA1200-174 | 174 | 5 – 100 | 3/16 – 4 | 200, 70 |
| BSA1200-258 | 258 | 5 – 200 | 3/16 – 8 | 200, 70 |
| BSS1200-300 | 300 | 5 – 300 | 3/16 – 12 | 400, 140 |

Capacities vary with grade as well as particle size

## *Dry LIMS – Belt separator (BSA and BSS)*






| Model | Drum DxL mm (ft) | W mm (inch) | Power kW/hp* | Weight ton |
|---|---|---|---|---|
| BSA1206 | 1200 x 600 (4x2) | 1800 (71) | 5,5/7,5 | 2,1 |
| BSA1212 | 1200x1200 (4x4) | 2400 (95) | 7,5/10 | 3,8 |
| BSA1218 | 1200x1800 (4x6) | 3000 (118) | 7,5/10 | 5,6 |
| BSA1224 | 1200x2400 (4x8) | 3600 (142) | 7,5/10 | 7,5 |
| BSA1230 | 1200x2400 (4x10) | 4200 (172) | 11/15 | 9,3 |
| BSS1212 | 1200x1200 (4x4) | 2400 (95) | 7,5/10 | 4,7 |
| BSS1218 | 1200x1800 (4x6) | 3000 (118) | 7,5/10 | 6,9 |
| BSS1224 | 1200x2400 (4x8) | 3600 (142) | 7,5/10 | 9,2 |

*) At peripheral drum speed 2 m/s (400 ft/min)

# *Dry LIMS – Drum separator, DS*

The Dry Drum Separator, DS, is generally used in iron ore beneficiation to either produce coarse final products or for reducing feed mass to following process stages. It is also used for steel slag and pyrite cinder treatment. The metal powder industry uses the separator for final product control.

## *Features*

- Magnetic system with four different pole pitches
- For low to high Fe grade feed
- Drum speeds up to 8 m/s (1600 ft/min)
- Top feed
- Adjustable product splitter for product quality control
- Coarse particle tolerant, normally up to 20 – 25 mm (3/4 – 1 inch)
- Basically used in primary stages as cobber and rougher
- Can be arranged in single stage or multistage processing
- Can be connected to dust control systems
- Large unit capacity



## *Recommended pole pitch*

| Pole pitch (pp) | Feed size mm | Feed size inch |
|---|---|---|
| (25) 45 | 0 – 5 | 0 – 3/16 |
| 45 | 0 – 10 | 0 – 3/8 |
| 65 | 0 – 15 | 0 – 9/16 |
| 112 | 0 – 20 | 0 – 3/4 |
| 174 | 0 – 25 | 0 – 1 |

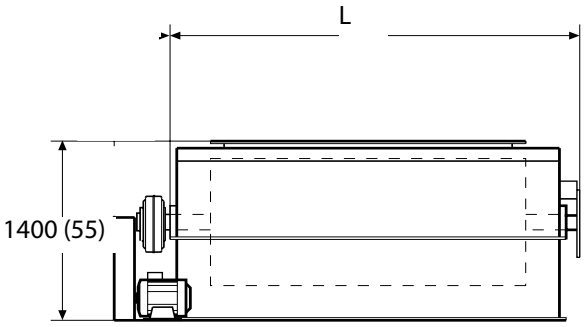
Note pp 25 is intended only for special application

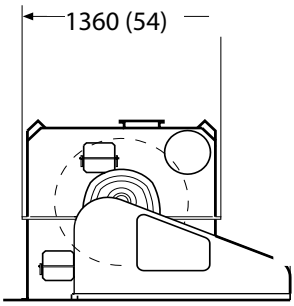
## *DS – Capacities*

| Type | Capacity t/h and m drum width | Capacity st/h /ft drum width |
|---|---|---|
| DS900 series | 50 – 150 | 15 – 45 |
| DS1200 series | 50 – 200 | 15 – 60 |

Capacities vary with grade and particle size

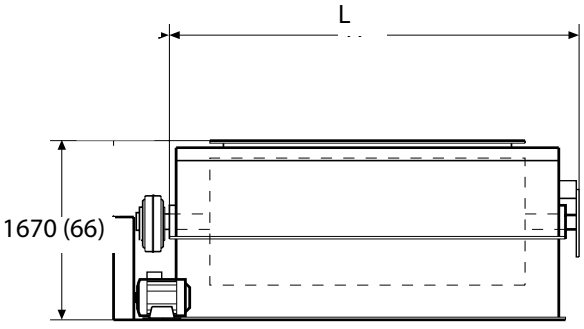
## *Dry LIMS – Drum separator – (DS)*

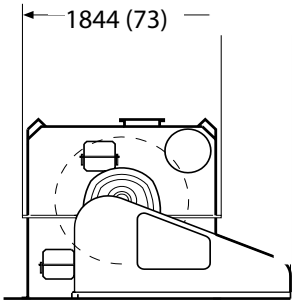



| Model | Drum dimensions DxL mm (ft.) | L mm (ft.) | Power kW/HP* | Weight empty Ton |
|---|---|---|---|---|
| DS906 | 916 x 600 (3x2) | 1550 (61) | 4/5 | 1,6 |
| DS912 | 916 x1200 (3x4) | 2170 (85) | 5,5/7,5 | 2,5 |
| DS918 | 916 x1800 (3x6) | 2780 (109) | 7,5/10 | 3,2 |
| DS924 | 916 x2400 (3x8) | 3400 (134) | 7,5/10 | 4,0 |






| Model | Drum dimensions DxL mm (ft.) | L mm (ft.) | Power kW/HP* | Weight empty Ton |
|---|---|---|---|---|
| DS1206 | 1200 x 600 (4x2) | 1550 (61) | 4/5 | 2,2 |
| DS1212 | 1200 x1200 (4x4) | 2170 (85) | 5,5/7,5 | 3,1 |
| DS1218 | 1200 x1800 (4x6) | 2780 (109) | 7,5/10 | 3,9 |
| DS1224 | 1200 x2400 (4x8) | 3400 (134) | 7,5/10 | 4,8 |
| DS1230 | 1200 x3000 (4x10) | 4020 (158) | 7,5/10 | 5,6 |

*) At drum peripheral speed of 2 m/s (400 ft/min)

## *Wet LIMS – Wet magnetic separators*

The wet magnetic separators are generally used in the iron ore industry in several stages of the process from coarse separation to fine concentration of magnetite ore, in single concentration means or in combination with other methods (e.g. flotation, gravity concentration, screening).

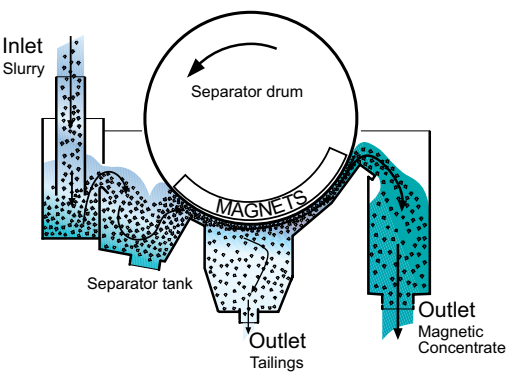
Wet LIMS are also used in other mineral industries for e.g. preparation of dense media, reduction of pyrrhotite content in base metal concentrates, removal of ferromagnetic contaminants etc.

Please always check with Metso for final selection!

## *Wet LIMS – Concurrent CC*

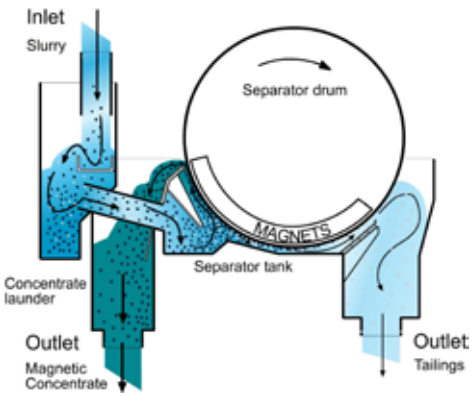


- Medium long magnetics pick up zone
- Standard magnetic system
- For low to high Fe grade feed
- Concurrent operation
- Tank bottom spigots for tailings flow control
- Coarse particle tolerant, normally up to 8 mm
- Basically used in primary stages as cobber and rougher
- Can be arranged as single stage or multistage units on same level for reprocessing of the magnetic product
- Large unit capacity
- Feed density acceptable in a wide range, normally 35 to 45 percent solids by weight



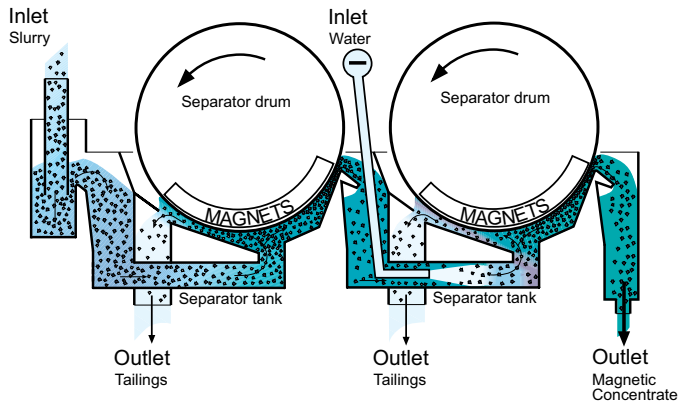
## *Wet LIMS – Counter rotation CR and CRHG*

- Extra long magnetics pick up zone
- Available with either standard or High Gradient magnetic systems
- For low to high Fe grade feed
- Counter rotational operation
- Manually adjustable weir for tailings flow control
- Coarse particle tolerant, normally up to 3-4 mm
- Basically used in primary stages as cobber or rougher
- Also used for dense media recovery
- Large unit capacity
- Mostly used in single unit operation but can installed as double units on two levels
- Feed density acceptable in a wide range, normally 25 to 45 percent solids by weight



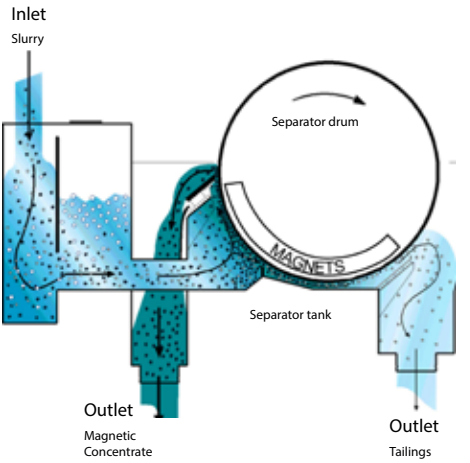

## *Wet LIMS – Countercurrent CTC and CTCHG*

- Long magnetics pick up zone
- Available with either standard or High Gradient magnetic systems
- Countercurrent operation
- Normally arranged installed as multistage units on same level for reprocessing of the magnetic product
- Fixed overflow weir for tailings flow control
- Medium particle tolerant, normally up to 0,8 mm
- Basically used in cleaning or finishing stages
- Feed density acceptable in a wide range, normally up to 40 percent solids by weight



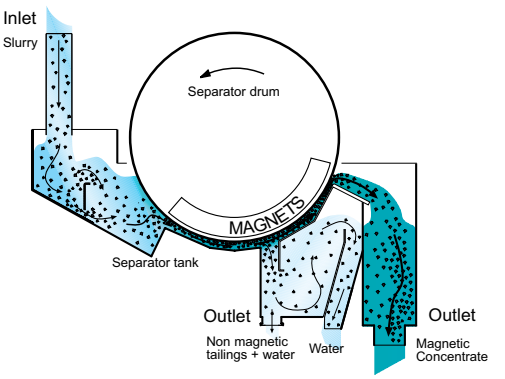
## *Wet LIMS – Counter rotation froth DWHG*

- Long magnetics pick up zone
- High Gradient magnetic systems
- Counter rotational operation
- Extra large feed box for deaeration of feed slurry
- Normally arranged installed as a single stage unit
- Manually adjustable weir for tailings flow control
- Coarse particle tolerant, normally up to 3-4 mm
- Designed to improve recovery from aerated (frothy) slurries
- Used for recovery of magnetics in slurries emanating from flotation
- Feed density acceptable in a wide range, normally up to 45 percent solids by weight

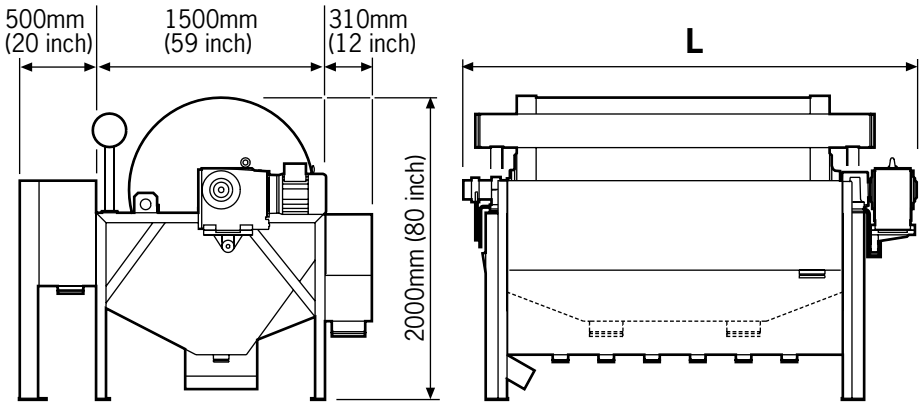



## *Wet LIMS – Dense media recovery DM and DMHG*

- Very long magnetics pick up zone
- Standard and High Gradient (HG) magnetic systems available
- For low to high Fe grade feed
- Concurrent operation with long magnetics pick-up zone
- Bottom spigots combined with effluent weir overflow for tailings flow control
- Coarse particle tolerant, normally up to 8 mm
- Used in both primary and secondary stages in single stage units



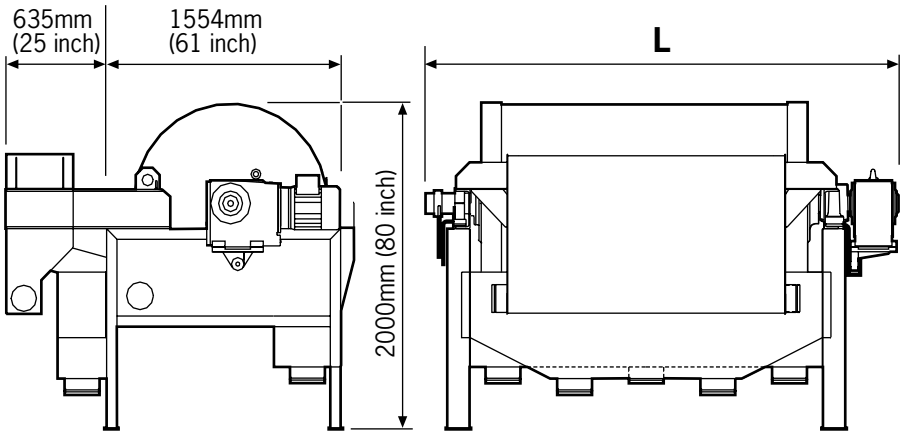
## *Wet LIMS – Concurrent (CC)*




| Model | Drum dimensions DxL mm (ft) | L mm (inch) | Power kW/HP | Weight (empty) ton |
|---|---|---|---|---|
| WS1206CC | 1200 x 600 (4x2) | 1810 (71) | 4 (5) | 1,9 |
| WS1212CC | 1200x1200 (4x4) | 2410 (95) | 5,5 (7,5) | 2,8 |
| WS1218CC | 1200x1800 (4x6) | 3010 (119) | 7,5 (10) | 3,6 |
| WS1224CC | 1200x2400 (4X8) | 3610 (142) | 7,5 (10) | 4,7 |
| WS1230CC | 1200x3000 (4x10) | 4218 (166) | 7,5 (10) | 5,6 |
| WS1236CC | 1200x3600 (4x12) | 4818 (190) | 11 (15) | 6,6 |

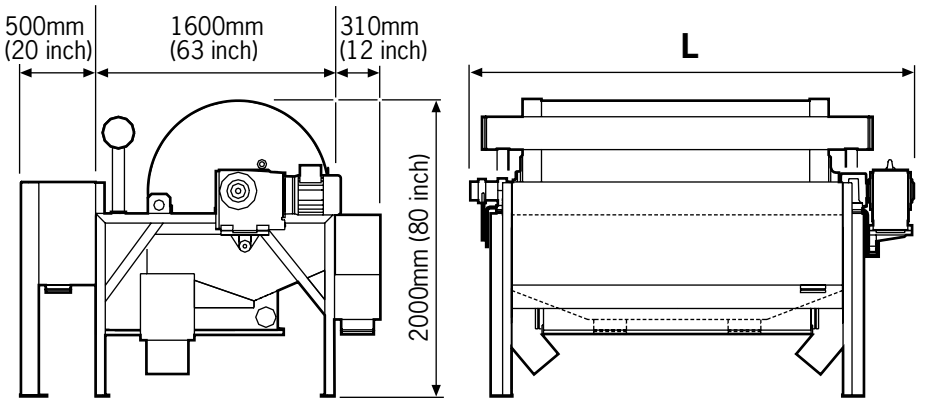


## *Wet LIMS – Counterrotation CR and CRHG*




| Model | Drum dimensions DxL mm (ft) | L mm (inch) | Power kW/hp | Weight (empty) ton |
|---|---|---|---|---|
| WS1206CR | 1200 x 600 (4x2) | 1810 (71) | 4/5 | 1,9 |
| WS1212CR | 1200x1200 (4x4) | 2410 (95) | 5,5/7,5 | 2,8 |
| WS1218CR | 1200x1800 (4x6) | 3010 (119) | 7,5/10 | 3,6 |
| WS1224CR | 1200x2400 (4X8) | 3610 (142) | 7,5/10 | 4,7 |
| WS1230CR | 1200x3000 (4x10) | 4218 (166) | 7,5/10 | 5,6 |
| WS1236CR | 1200x3600 (4x12) | 4818 (190) | 11/15 | 6,6 |

## *Wet LIMS – Countercurrent CTC and CTCHG*

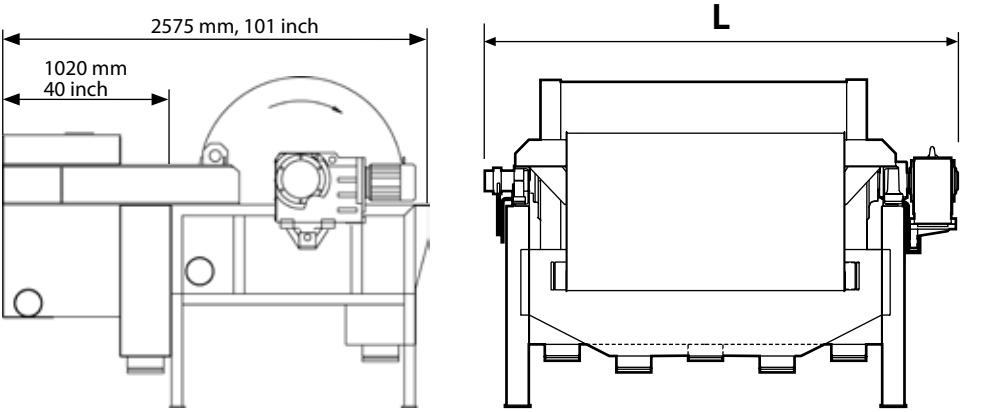





| Model | Drum dimensions DxL mm (ft) | L mm (inch) | Power kW/hp | Weight (empty) ton |
|---|---|---|---|---|
| WS1206CTC | 1200 x 600 (4x2) | 1810 (71) | 4/5 | 1,9 |
| WS1212CTC | 1200x1200 (4x4) | 2410 (95) | 5,5/7,5 | 2,8 |
| WS1218CTC | 1200x1800 (4x6) | 3010 (119) | 7,5/10 | 3,6 |
| WS1224CTC | 1200x2400 (4X8) | 3610 (142) | 7,5/10 | 4,7 |
| WS1230CTC | 1200x3000 (4x10) | 4218 (166) | 7,5/10 | 5,6 |
| WS1236CTC | 1200x3600 (4x12) | 4818 (190) | 11/15 | 6,6 |

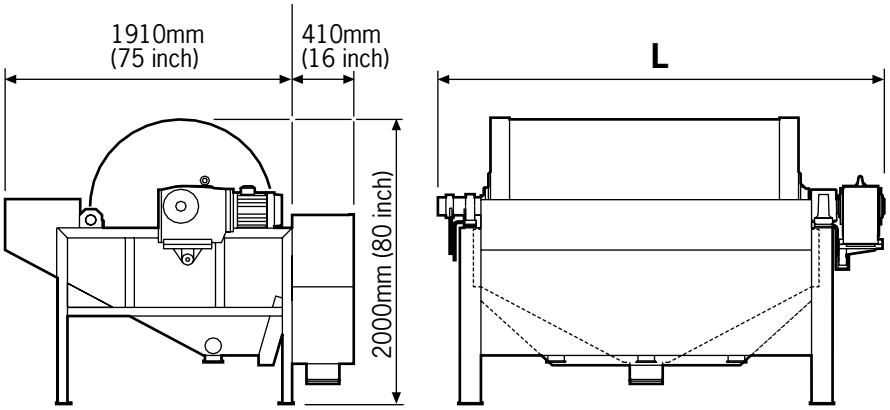
WS1200CTC and WS1200CTCHG carry identical dimensions

## *Wet LIMS – Counter rotation froth DWHG*




| Model | Drum dimensions DxL mm (ft) | L mm (inch) | Power kW/hp | Weight (empty) ton |
|---|---|---|---|---|
| WS1206DWHG | 1200 x 600 (4x2) | 1810 (71) | 1,5/2,0 | 1,9 |
| WS1212DWGH | 1200x1200 (4x4) | 2410 (95) | 2,2/3,0 | 2,8 |
| WS1218DWHG | 1200x1800 (4x6) | 3010 (119) | 3,0/4,0 | 3,6 |
| WS1224DWHG | 1200x2400 (4X8) | 3610 (142) | 3,0/4,0 | 4,7 |
| WS1230DWHG | 1200x3000 (4x10) | 4218 (166) | 4,0/5,0 | 5,6 |
| WS1236DWHG | 1200x3600 (4x12) | 4818 (190) | 4,0/5,0 | 6,6 |

## *Wet LIMS – Dense media DM and DMHG*

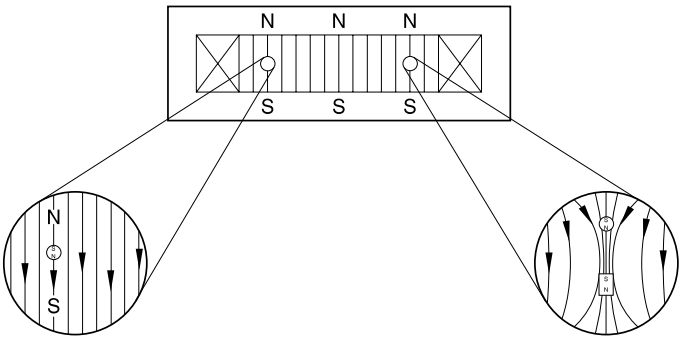



| Model | Drum dimensions D x L mm (ft) | L mm (inch) | Power kW/hp | Weight (empty) ton |
|---|---|---|---|---|
| WS1206DM | 1200 x 600 (4x2) | 1810 (71) | 1,5/2,0 | 1,9 |
| WS1212DM | 1200x1200 (4x4) | 2410 (95) | 2,2/3,0 | 2,8 |
| WS1218DM | 1200x1800 (4x6) | 3010 (119) | 3,0/4,0 | 3,6 |
| WS1224DM | 1200x2400 (4X8) | 3610 (142) | 3,0/4,0 | 4,7 |
| WS1230DM | 1200x3000 (4x10) | 4218 (166) | 4,0/5,0 | 5,6 |
| WS1236DM | 1200x3600 (4x12) | 4818 (190) | 4,0/5,0 | 6,6 |

WS1200DM and WS1200DMHG carry identical physical dimensions

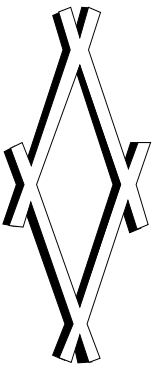
## *Wet HGMS/F – Magnet design*

The HGMS and HGMF magnet design provides a uniform magnetic field in the canister (separation vessel). The uniform field in itself cannot alone create any separation process but by insertion of sharply edged ferromagnetic material, a matrix, in the void the magnetic field is greatly disturbed and the required magnetic field gradient for the process is produced in the separation space.

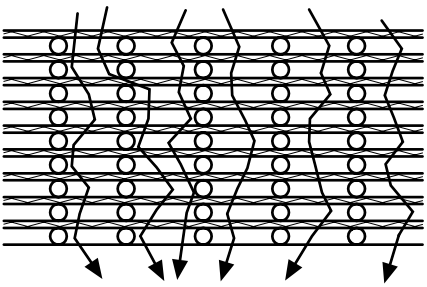



*Homogeneous field (Fm=0)*

*Inhomogeneous field (Fm>0)*



*Filament*



*Filament matrix*

### *Facts about Matrix*

- Made of ferromagnetic stainless steel as expanded metal (X) or as steel wool (W)
- Matrix grade (opening size) is selected to suit particle size and properties
- The disturbing material, matrix, is filling the process space volumetrically to 15 to 20 % of the void of the process space.
- Due to the controlled pulp velocity through the matrix, the matrix material wear rate is extremely low.

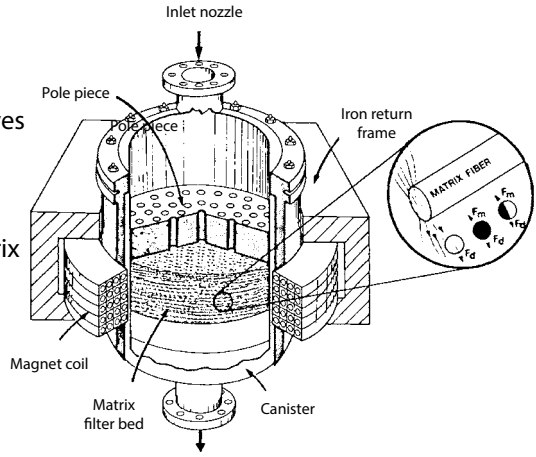
## *Wet HGMS, HGMF – Separator types*

| | |
|---|---|
| Cyclic separators, HGMS | For applications with low magnetic content in the feed, normally less than 4 - 5 % |
| Cyclic separators, HGMF | Also called magnetic filter, designed similar to cyclic HGMS but specially outfitted for removal of magnetic content of effluents. |
| Continuous Separators | For mineral separation with magnetic content in feed higher than 4 %. |

## *Wet cyclic HGMS*

- Robust and simple design
- No moving parts except for valves
- Magnetic field intensity up to 2T (20kG)
- Extremely long wear life of matrix
- Extremely low maintenance requirement
- Generally fully automated operation

See data sheet page 5:37.




### *Models and dimensions*

The cyclic unit models are defined by canister diameter, matrix height and magnetic field.



### *HGMS canister size – matrix area*

| Model | Canister OD mm | Canister OD inch | Matrix area $m^2$ |
|---|---|---|---|
| HGMS10 | 36 | 1,4 | 0,00099 |
| | 86 | 3,4 | 0,0057 |
| HGMS22 | 168 | 6,6 | 0,019 |
| HGMS38 | 324 | 12,8 | 0,078 |
| HGMS46 | 406 | 16 | 0,118 |
| HGMS56 | 508 | 20 | 0,187 |
| HGMS66 | 660 | 26 | 0,323 |
| HGMS76 | 763 | 30 | 0,433 |
| HGMS107 | 1 067 | 42 | 0,862 |
| HGMS152 | 1 524 | 60 | 1,778 |
| HGMS214 | 2 134 | 84 | 3,511 |
| HGMS305 | 3 084 | 120 | 7,175 |

### *Matrix heights*

| Matrix heights nomination | Matrix heights mm | Matrix heights inch |
|---|---|---|
| 15 | 150* | 6* |
| 15 | 178 | 7 |
| 30 | 305 | 12 |
| 50 | 503 | 20 |

*) available only with model HGMS10

**Standard magnetic field designs**

The available magnetic field designs have been limited to 3, 5, 10, 15 and 20. The available magnetic field can always be adjusted to a lower rating. The highest available rating appears as the last digit(s) in the HGMS model name.

## *Model definition*

In the model name canister diameter, matrix height and nominal magnetic rating are appearing, e.g. HGMS107-15-10 had a diameter of 1067mm a matrix height of 178 mm and a magnetic rating of 10 kG.

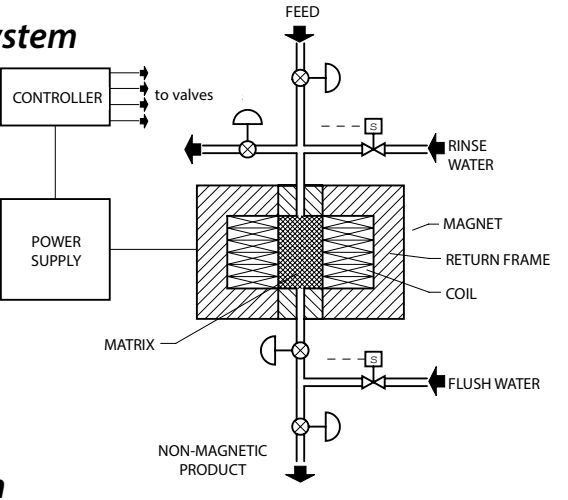
## *Matrix grades for cyclic HGMS units*

| Matrix grade | Type of matrix | Maximum particle size, µm | Maximum particle size, mesh |
|---|---|---|---|
| XR1.1 | Expanded metal | 1000 | 16 |
| XR | Expanded metal | 800 | 22 |
| XM1.1 | Expanded metal | 450 | 35 |
| XM | Expanded metal | 350 | 42 |
| XMG0 | Expanded metal | 300 | 48 |
| XF1.1 | Expanded metal | 150 | 106 |
| XF | Expanded metal | 100 | 150 |
| WC | Steel wool | 20 | |
| WM | Steel wool | 10 | |
| WF | Steel wool | 7 | |

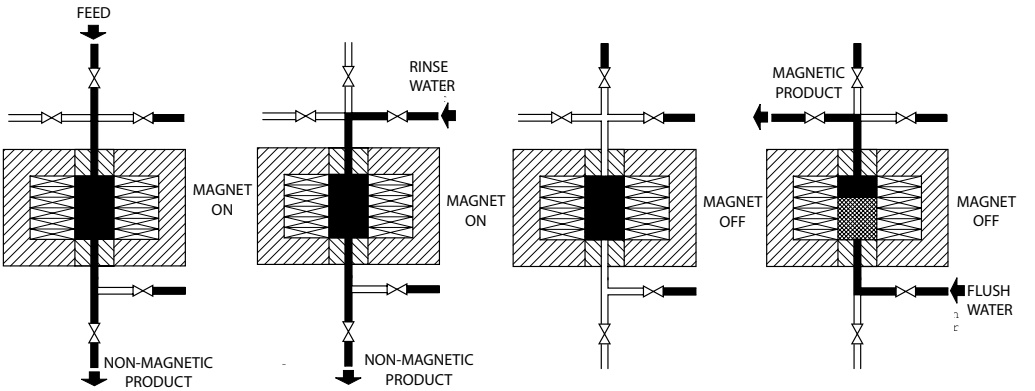


## *Wet cyclic HGMS – Process system*

- Compact system design
- Fail-safe protection (thermal)
- Customer built power supply
- Completely automatic process control




## *Wet cyclic HGMS – Operation*




**Cycle 1 Separation**
- Magnet activated
- Feed on

**Cycle 2 Rinse**
- Magnet activated
- Feed off
- Washing on

**Cycle 3 Demagnetizing**
- Magnet off
- Feed off
- Washing off

**Cycle 4 Flushing**
- Magnet off
- Feed off
- Washing on

### *Typical cycle times (Kaolin separation):*

| | |
|---|---|
| Separation | 4 min. |
| Rinse | 1.5 min. |
| Magnetizing / Demagnetizing | < 1 min. |
| Flush | < 1 min. |

## *Wet cyclic HGMS – Applications*

- Kaolin beneficiation (brightening)
- $Fe_2O_3$ reduction in glass sand, feldspar, barite
- Cu-reduction in Mo Cu concentrates
- De-ashing and desulphurisation of coal
- Phosphates upgrading
- Testing and research (Laboratory unit HGMS10-15-20)



## *Wet cyclic HGMS – Sizing (indicative)*

**Ex: Cleaning of kaolin clay, 4 t/h. Select the separator size.**

1. Calculate the cycle time:

| | |
|---|---|
| • Feed | 4 min. |
| • Rinse | 1.5 min. |
| • Magnet on/off | 1 min. |
| • Flushing | 1 min. |
| ***Total cycle time*** | ***7.5 min.*** |

2. Calculate the actual separation time (feed) from 1. above

   4 / (4 + 1,5 + 1 + 1) = 4 / 7,5 = 0,53 (53%)

3. Calculate the volume flow of 4.0 t/h (at say 25% solids and S.G. 2.5) which gives 13.6 $m^3$/h (0.75 ft / min)

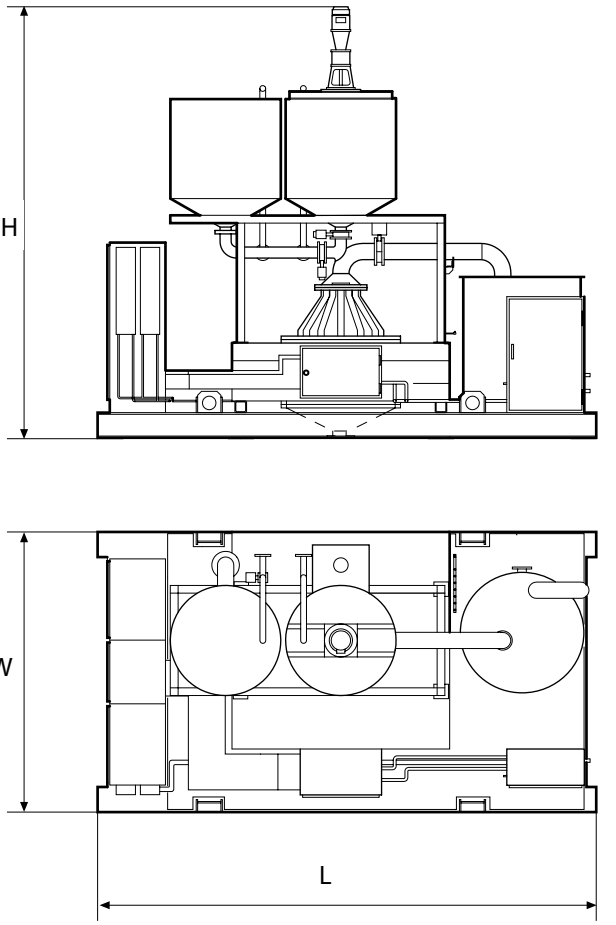
   As actual separation time is 53% of total time, separator volumetric capacity must be = 13,6/0,53 = 25,7 $m^3$/h (15.1 cuft / min)

4. Kaolin (very fine particles) means matrix of W-type. Typical flow velocity for kaolin processing is 8 mm/s or 28,8 m/h (19.0 inch / min)

5. Calculate separator size
   matrix area ($m^2$) = volume capacity ($m^3$/h) / flow velocity (m/h) = 25,7 / 28,8 = 0,89 $m^2$ (9.6 sqft)

   Machine size, see above, is HGMS 107-30-20

## *Wet cyclic HGMS*






| Model | H mm (ft) | L mm (ft) | W mm (ft) | Power (magnet) kW | Weight (empty) ton | Matrix area $m^2$ ($ft^2$) |
|---|---|---|---|---|---|---|
| 38-15-10* | 4 000 (13) | 3 800 (12) | 2 450 (8) | 40 | 10 | 0.11 (1.18) |
| 56-15-10 | 4 100 (13) | 4 000 (13) | 2 450 (8) | 46 | 13 | 0.19 (2.05) |
| 76-15-10 | 4 100 (13) | 4 200 (14) | 2 450 (8) | 53 | 14 | 0.43 (4.63) |
| 107-15-10 | 4 380 (14) | 5 150 (17) | 2 900 (10) | 63 | 26 | 0.85 (9.15) |
| 152-15-10 | ** | ** | ** | 80 | 46 | 1.75 (18.84) |
| 214-15-10 | ** | ** | ** | 103 | ** | 3.42 (36.81) |
| 305-15-10 | ** | ** | ** | - | ** | 7.30 (78.58) |

*38-15-10= 38(Outer diameter in cm)-15 (matrix height in cm) -10 (field rating in kGauss)

Magnetic field available 5,10,15 and 20 kGauss

** Site specific

## *Wet cyclic high gradient magnetic filter HGMF*

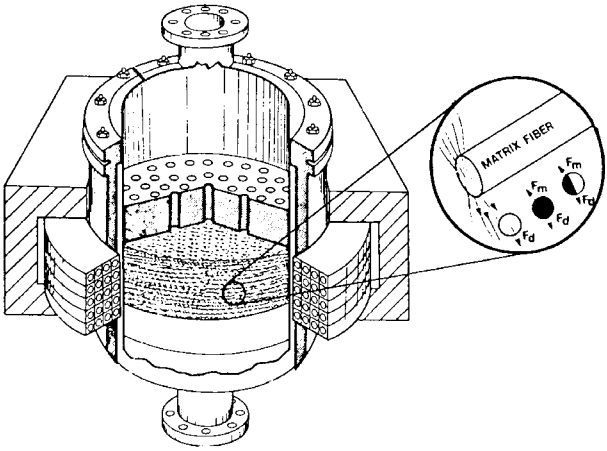
The Cyclic HGMF is in principle based on the cyclic HGMS but arranged to work as filter instead of as separator. It is normally used for magnetic filtration of liquids and effluents.

### *Features*

- Robust and simple design
- No moving parts except for valves
- Magnetic field intensity up to 2T (20kG)
- Extremely long wear life of matrix
- Extremely low maintenance requirement
- Generally fully automated operation
- Can be arranged for special process requirements like high pressure and temperatures

See data sheet page 5:41.






### *Models and sizes*

The cyclic HGMF units are defined by canister diameter, matrix height and magnetic field.

The laboratory model is available as HGMS10-15-20 and is used for both HGMS and HGMF investigations.

## HGMF – Canister diameters and matrix areas

| Model | Canister OD mm | Canister OD inch | Matrix area $m^2$ |
|---|---|---|---|
| HGMS10 | 36 | 1,4 | 0,00099 |
| | 86 | 3,4 | 0,0057 |
| HGMF22 | 168 | 6,6 | 0,019 |
| HGMF38 | 324 | 12,8 | 0,078 |
| HGMF46 | 406 | 16,0 | 0,118 |
| HGMF56 | 508 | 20,0 | 0,187 |
| HGMF66 | 660 | 26,0 | 0,323 |
| HGMF76 | 763 | 30,0 | 0,433 |
| HGMF107 | 1 067 | 42,0 | 0,862 |
| HGMF152 | 1 524 | 60,0 | 1,778 |
| HGMF214 | 2 134 | 84,0 | 3,511 |
| HGMF305 | 3 084 | 120,0 | 7,175 |



## Matrix heights

| Matrix heights nomination | Matrix heights mm | Matrix heights inch |
|---|---|---|
| 15 | 150* | 6* |
| 15 | 178 | 7 |
| 30 | 305 | 12 |
| 50 | 503 | 20 |

*) available only with model HGMS10

## Standard magnetic field designs

The available magnetic field designs have been limited to 3, 5, 10, 15 and 20. The available magnetic field can always be adjusted to a lower rating. The highest available rating appears as the last digit(s) in the HGMS model name.

## Model definition

In the model name canister diameter, matrix height and nominal magnetic rating are appearing, e.g. HGMF107-15-10 has a diameter of 1067mm a matrix height of 178 mm and a magnetic rating of 10 kG.

## Matrix grades for cyclic HGMF units

| Matrix grade | Type of matrix | Maximum particle size, µm | Maximum particle size, mesh |
|---|---|---|---|
| XR1.1 | Expanded metal | 1000 | 16 |
| XR | Expanded metal | 800 | 22 |
| XM1.1 | Expanded metal | 450 | 35 |
| XM | Expanded metal | 350 | 42 |
| XMG0 | Expanded metal | 300 | 48 |
| XF1.1 | Expanded metal | 150 | 106 |
| XF | Expanded metal | 100 | 150 |
| WC | Steel wool | 20 | |
| WM | Steel wool | 10 | |
| WF | Steel wool | 7 | |

## HGMF - Applications

Generally: For high pressure, high temperature and "lack of space" applications

- Removal of iron and copper particles from boiler circuits
- Cleaning of district heating systems
- Removal of weakly magnetic particles from process water (mill scale, metallurgical dust etc.)

## HGMF – Process data

**Solids in feed** Normally low ppm levels

**Particle size in feed** Restricted by matrix type
Matrix type XF will allow particles – 100 microns

## HGMF – Sizing

Sizing similar to conventional clarification sizing, see section 6:3.

Surface load $(m^3/h)/m^2$ and $(ft^3/h)/ft^2$ is the flow velocity through the matrix for optimal clarification.

| Application * | Surface load $(m^3/h)/m^2$ | Surface load $(ft^3/h)/ft^2$ | Flush interval |
|---|---|---|---|
| Condensate polishing | 500 – 1 500 | 27 – 81 | 7 – 21 days |
| District heating systems | 500 – 1 500 | 27 – 81 | 24 hours |
| Steel mill cooling water | 200 – 800 | 11 – 44 | 0.3 – 1 hours |

* Magnetic field 3 kg

**Ex 1:**

*Steel mill cooling water can be treated with a surface load of 500 $(m^3/h)/m^2$ at 3 kG. The flow is 800 $m^3/h$.*

*Required area 800 / 500 = 1.6 $m^2$*

***Select HGMF 152 - 15 - 3***

**Ex 2:**

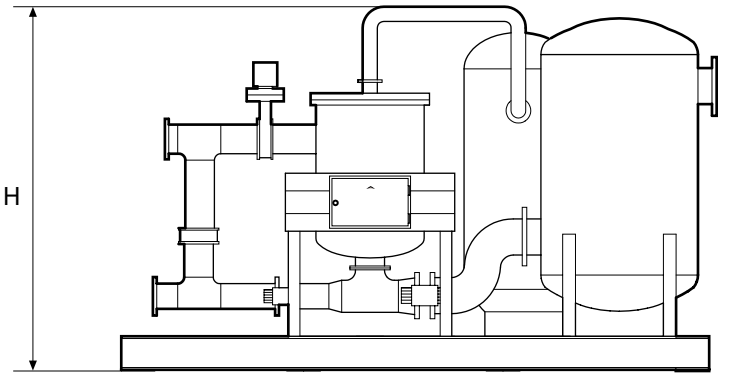
*Paper mill Condensate water can be treated with a surface load of approx. 500 GPMPSF (Gallon per minute per square foot)*

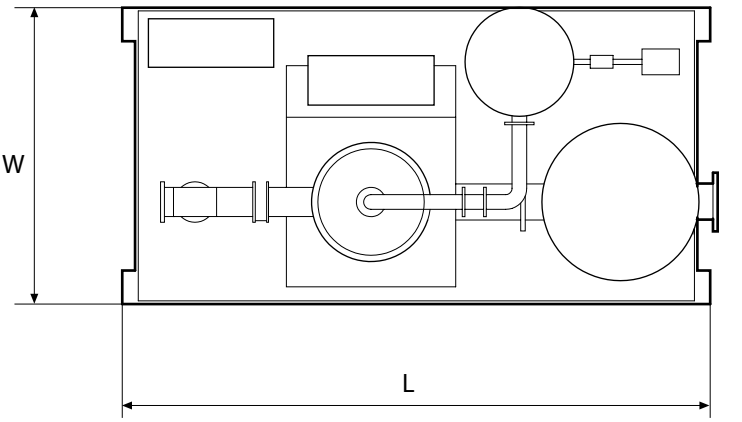
*Flow is 3000 GPM*

*HGMF model 107 has an area = 9.1 $ft^2$*

***3000 / 9.1 = 330 GPMPSF (OK!)***

# *Wet cyclic high gradient magnetic filter – HGMF*




| Model | H mm (ft) | L mm (ft) | W mm (ft) | Power (magnet) kW | Matrix area $m^2$ ($ft^2$) |
|---|---|---|---|---|---|
| 38-15-3* | 1 905 (6) | 3 048 (10) | 1 321 (4) | 9 | 0.07 (0.8) |
| 45-15-3 | 2 032 (7) | 3 556 (12) | 1 524 (5) | 12 | 0.11 (1.2) |
| 56-15-3 | 2 210 (7) | 4 064 (13) | 1 829 (6) | 12 | 0.19 (2.0) |
| 76-15-3 | 2 464 (8) | 4 115 (14) | 1 829 (6) | 24 | 0.43 (4.6) |
| 107-15-3 | 3 073 (10) | 5 588 (18) | 1 981 (7) | 24 | 0.85 (9.15) |
| 152-15-3 | ** | ** | ** | 28 | 1.75 (18.84) |
| 214-15-3 | ** | ** | ** | 37 | 3.42 (36.81) |

*38-15-3= 38 (Outer diameter in cm)-15 (matrix height in cm) -3 (field rating in kGauss)

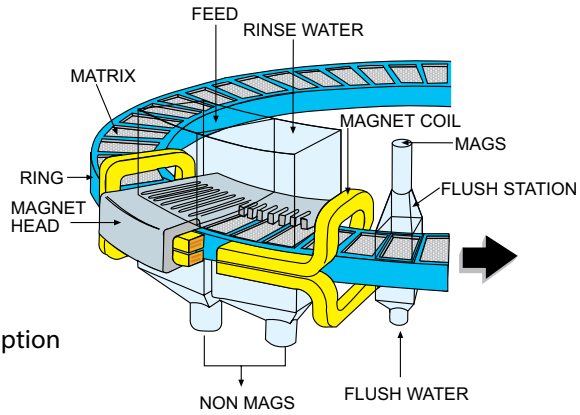
Magnetic field available 3,5,10,15 and 20 kGauss

** Site specific

## *Wet continuous HGMS*

**Features**

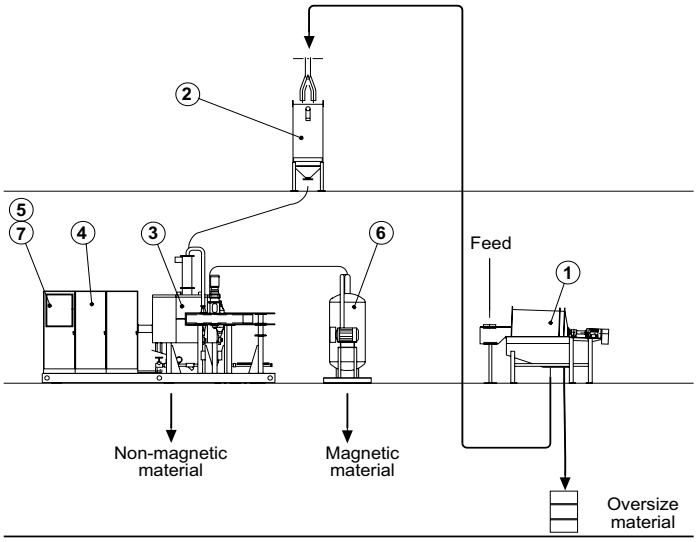
- Continuous operation
- Fully automatic processing
- Broad range of applications
- Fine particle processing
- High separation efficiency
- Reliable design
- Low specific power consumption
- Large process capacity
- Long component life




See data sheet page 5:44

## *Wet continuous HGMS – Process system*

1. Oversize control
2. Passive matrix
3. Separator
4. Power supply
5. Cooling system
6. Vacuum system
7. Control system




## *Wet continuous HGMS – Applications*

**1. Concentration of paramagnetic oxide minerals such as:**

- Chromite
- Hematite
- Ilmenite
- Manganite
- Volframite

2. Rare earth minerals
3. Industrial minerals (reduction of paramagnetic contaminations)
4. Coal (desulphurization and de-ashing)
5. Separation of base metal minerals such as:
   - Cu-Mo
   - Cu-Pb
   - Zn-Pb

## *Wet continuous HGMS – Sizing and selection*

Note: The sizing and selection of the equipment should be carried out by authorized personnel.

**Matrix loading (ML)** = Allowable feed solids (dry weight) per matrix volume, g/cm3.

**Pulp flow velocity (PFV),** mm/s

The factors feed density, Magnetic field, ML and PFV are determined by laboratory testing. The data in the tables below are only indicative.

### *Matrix grades for continuous HGMS units*

| Matrix grade | Type of matrix | Maximum particle size, µm | Maximum particle size, mesh |
|---|---|---|---|
| XR1.1 | Expanded metal | 1000 | 16 |
| XR | Expanded metal | 800 | 22 |
| XM1.1 | Expanded metal | 450 | 35 |
| XM | Expanded metal | 350 | 42 |
| XMG0 | Expanded metal | 300 | 48 |
| XF1.1 | Expanded metal | 150 | 106 |
| XF | Expanded metal | 100 | 150 |



### *Wet continuous HGMS – Approximate water consumption*

| Size | Rinse/mag head ($m^3$/h) | Flush/mag head ($m^3$/h) | Seal water/unit ($m^3$/h) | Cooling water* ($m^3$/h) |
|---|---|---|---|---|
| 120 | 15 | 20 | 8 | 3 |
| 185 | 70 | 90 | 12 | 4 |
| 250 | 200 | 250 | 27 | 6 |
| 350 | 350 | 450 | 40 | 9 |

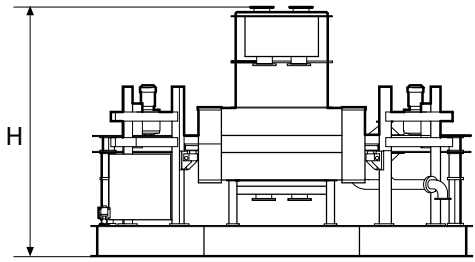
* One magnet head 7 kGauss

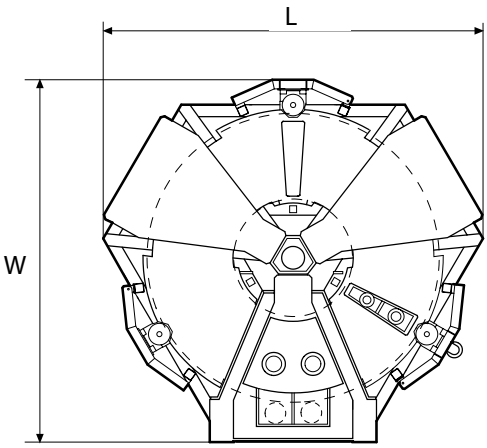
| Size | Rinse/mag head (USGPM) | Flush/mag head (USGPM) | Seal water/unit (USGPM) | Cooling water* (USGPM) |
|---|---|---|---|---|
| 120 | 65 | 90 | 35 | 15 |
| 185 | 310 | 395 | 50 | 20 |
| 250 | 880 | 1 095 | 120 | 25 |
| 350 | 1 535 | 1 975 | 175 | 40 |

* One magnet head 7 kGauss

| Application | Magnetic field T | Matrix loading g/cm3 | Flow velocity mm/s |
|---|---|---|---|
| Hematite | 0,3 – 0,7 | 0,3 – 0,65 | 180 – 250 |
| Martite | 0,3 – 0,7 | 0,3 – 0,6 | 180 – 250 |
| Ilmenite | 0,5 – 0,7 | 0,3 – 0,45 | 180 – 200 |
| Chromite | 0,5 – 0,7 | 0,3 – 0,5 | 150 – 200 |
| Manganese | 1,0 – 1,5 | 0,3 – 0,5 | 100 – 200 |
| Apatite | 0,7 – 1,5 | 0,3 | 100 – 150 |
| Kyanite | 1,5 | 0,3 | 100 – 150 |
| Wolframite | 1,0 | 0,3 | 100 – 150 |
| Nepheline Syenite | 1,2 – 1,5 | 0,3 | 60 – 90 |
| Glass sand | 1,5 | 0,3 – 1,0 | 60 – 90 |
| Mica | 0,8 – 1,0 | 0,3 – 0,8 | 60 – 90 |
| Retreatment of current tailings and exist. deposits | Varying | Varying | Varying |

## *Wet continuous HGMS*





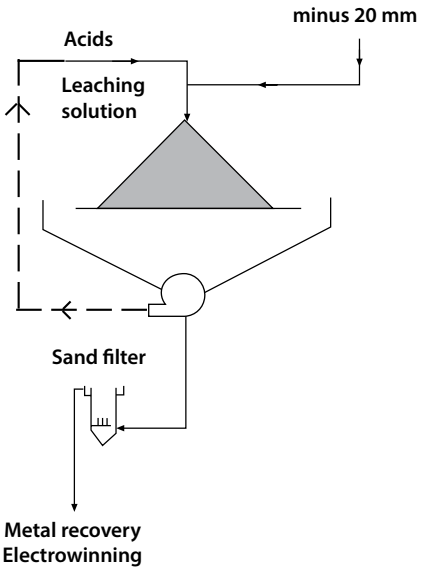

| Model | H mm (ft) | L mm (ft) | W mm (ft) | Power/head* kW | Weight/frame ton | Weight/head ton |
|---|---|---|---|---|---|---|
| 120-10 (2)* | 2 800 (9) | 2 600 (9) | 2 200 (7) | 75 | 6 | 3 |
| 120-15 (2) | 2 800 (9) | 2 600 (9) | 2 200 (7) | 175 | 5 | 5 |
| 185-7 (2) | 3 600 (12) | 4 100 (13) | 3 700 (12) | 65 | 10 | 9 |
| 185-10 (2) | 3 600 (12) | 4 100 (13) | 3 700 (12) | 85 | 10 | 18 |
| 185-15 (2) | 3 600 (12) | 4 100 (13) | 3 700 (12) | 200 | 10 | 31 |
| 250-5 (2) | 3 600 (12) | 6 300 (21) | 4 500 (15) | 40 | 20 | 22 |
| 250-7 (2) | 3 600 (12) | 6 300 (21) | 4 500 (15) | 75 | 20 | 32 |
| 250-10 (2) | 3 600 (12) | 6 300 (21) | 4 500 (15) | 120 | 20 | 54 |
| 250-15 (2) | 3 600 (12) | 6 300 (21) | 4 500 (15) | 260 | 20 | 95 |
| 350-5 (3) | 4 600 (15) | 7 000 (23) | 7 500 (25) | 78 | 40 | 26 |
| 350-7 (3) | 4 600 (15) | 7 000 (23) | 7 200 (24) | 136 | 40 | 37 |
| 350-10 (3) | 4 600 (15) | 7 200 (24) | 7 200 (24) | 165 | 40 | 66 |
| 350-15 (2) | 4 600 (15) | 8 200 (27) | 7 000 (23) | 326 | 40 | 120 |

* power required for ring drive, cooling systems lubrication etc is additional.

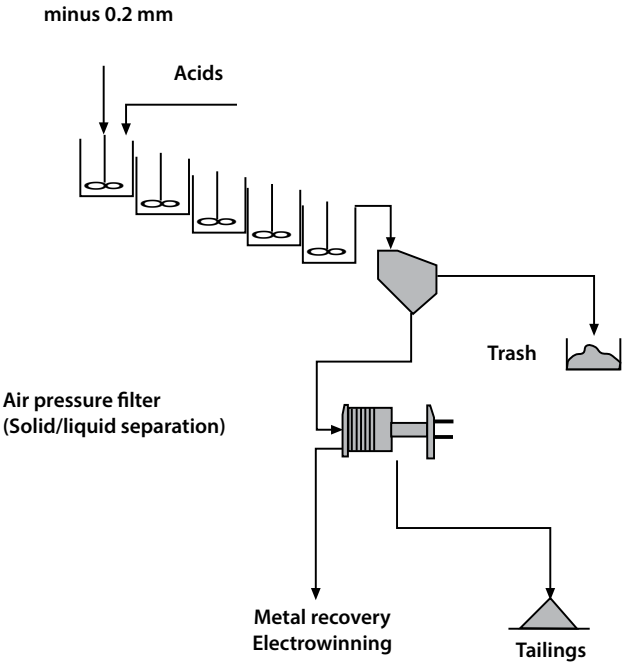
## *Leaching of metals*

Below find the flow sheets for classical leaching circuits, heap leaching for coarse fractions (crushing only) of low grade ores and agitation leaching for finer fraction of high value ores.

In the **heap leaching** process the ground is protected by a sealed surface, collecting the leaching chemicals, re- circulated by pumping. When the solution is "pregnant" its clarified by sedimentation or sand filtration and taken to metal recovery by electrowinning.




In the **agitation leaching** circuit the feed is finer (typical –200 microns) and the slurry moves in the same direction as the chemicals (con current flow). In this case, the pregnant solution has to be recovered from the solids by mechanical dewatering due to particle size, see section 6.



## *Gold leaching*

Enrichment by leaching is mainly used for recovery of gold often in combination with pre separation by gravity. If free coarse gold is released during size reduction, this fraction (typical – 1mm) is recovered in gravity spirals, see 5:8. If finer fractions of free gold are present centrifuge technology can be applied (not covered here). Alternatively, when processing an ore containing gold metal only, leaching with carbon adsorption are frequently used.

## *Gold leaching – Carbon adsorption*

**Leaching reaction**

$$2\,Au + 4\,CN^- + O_2\,(air) + 2H_2O \longrightarrow 2\,Au\,(CN)_2^- + OH^-\ pH>8\ (lime)$$

**Process stages**

1. ***Leaching*** by agitation to dissolve Au by reaction above. Agitators are arranged in con current flow.
   **CIL (Carbon in leach)** is a method where the gold adsorption by carbon is done in the leaching circuit. The method, seldom used due to high operating costs, is not covered here.

2. ***CIP (Carbon in pulp) adsorption*** by slow agitation using active carbon granules to adsorb the Au solution from the pulp. Agitators are arranged in counter current flow (carbon travelling towards the pulp flow).
   See flowsheet on next page.

   Carbon granules must be:

   ***a. Hard*** to resist abrasion (made from coconut shells)

   ***b. Coarse*** to be separated from slurry by sizing (1-3 mm, 16-6 Mesh)

   ***c. High*** in specific surface

3. **Carbon recovery** is done by sizing over a screen (cut at 0,7 mm, 24 Mesh) bringing the loaded carbon out of the pulp system

4. **Au stripping** is the process of removing the gold solution by "washing" the carbon granules in a solution (cyanide + Na OH) at 135°C. (retention time 6-8 hours).

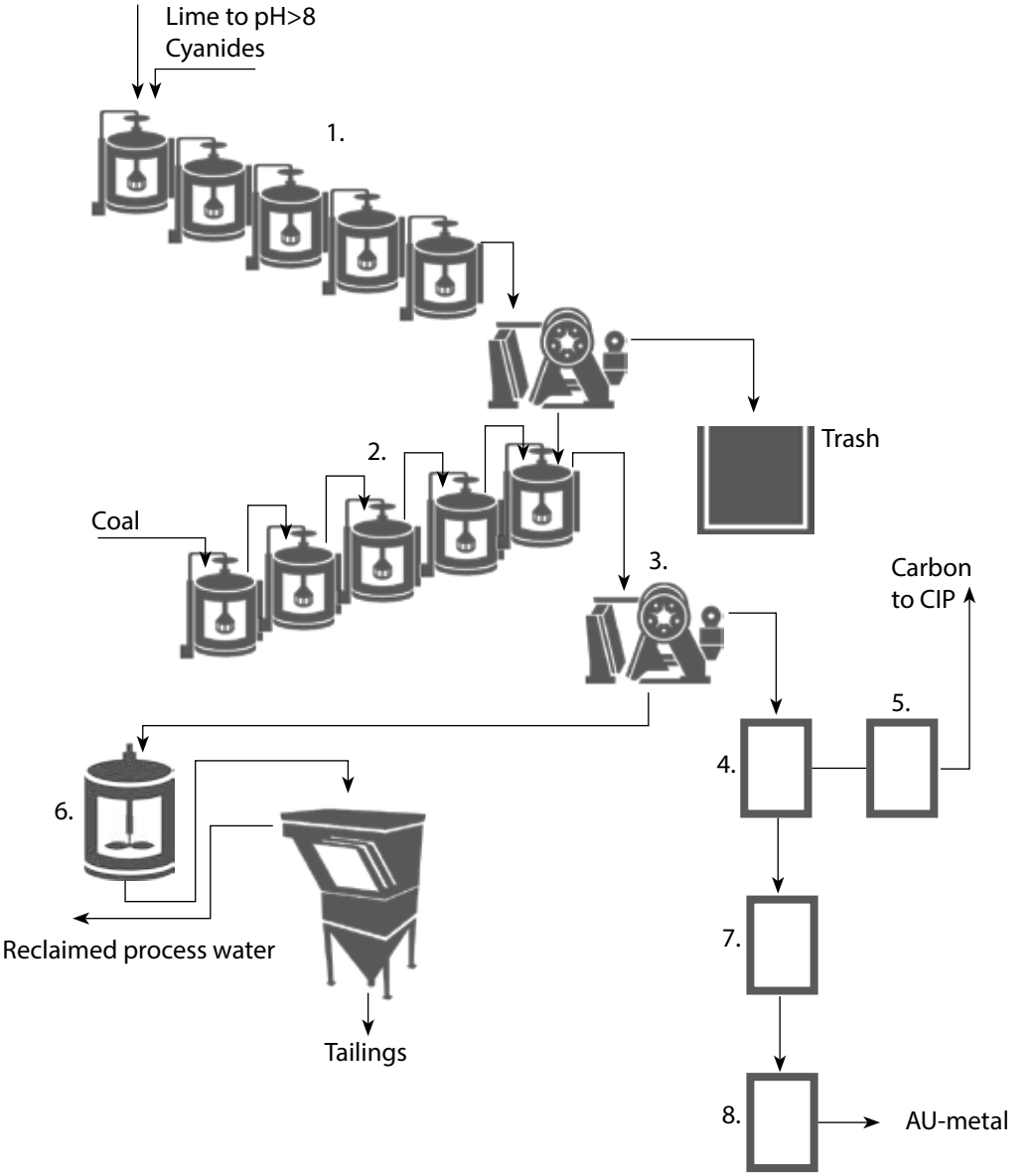
5. **Carbon reactivation** is needed after the washing to restore the active surface of the granules. This is done in a kiln at 125° C

6. **Cyanide destruction** of the pulp leaving the CIP circuit is done in an agitator adding an oxidant (typical hypocloride) bringing remaining cyanide to a harmless state.

7. **Au electrowinning** by plating out the gold metal is done with steel wool cathodes. These cathodes are sent to fluxing and smelting (8).

## *Gold leaching – CIP*

### *From grinding circuit, typical – 75 micron (200 mesh)*




Agitation, see 8:31.

Sedimentation, see 6:2.

Mechanical dewatering, see 6:24.

## *Upgrading – Introduction*

With upgrading we understand, the further processing of the final products from the enrichment stages in a process.
This is valid both concerning the valuable minerals (the concentrate) and the waste minerals (the tailings).

In the first case upgrading means improving the product value by bringing the concentrate to transportability or into a completely dry form. Processing can also go further to calcining and sintering.
On the tailing side upgrading means that waste material (wash water, process effluents etc.) is properly taken care of in order to protect the environment, to recover process water and to turn certain portions into valuables.

## *Upgrading by methods*

**Sedimentation**
Clarification/Thickening (conventional)
Clarification/Thickening (compact)

**Mechanical dewatering**
Gravity
Low pressure
Medium pressure
High pressure

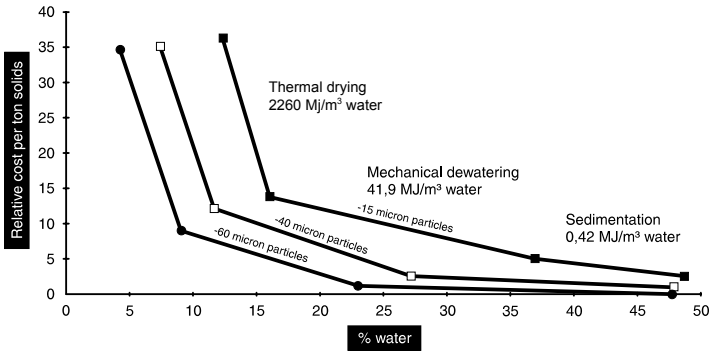
**Thermal drying**
Direct
Indirect

**Thermal processing**
Calcining
Sintering (pelletizing)



## *Upgrading by operation costs*

Upgrading has its price, increasing with the energy input for removal of the process water (or process liquid).




The curves above must always be considered when we are selecting equipment for an upgrading circuit for concentrate drying or disposal of a washing effluent.
The rules are simple!

1. Can we do the job with sedimentation only? If not – how far can we reach by sedimentation thereby saving money in the following dewatering stage?
2. How far can we reach with mechanical dewatering? Can we save a thermal stage by increasing the dewatering pressure?
3. If the particles are coarse, can gravity dewatering do the job? The cost is close to the same as for sedimentation.
4. If thermal dewatering is needed, can energy be saved in drying by improved mechanical dewatering?

# Sedimentation

Sedimentation is a continuous solid-liquid separation process with settling of solids by gravity. **Clarification** is the process for removal of solids from a dilute solid/liquid suspension. **Thickening** is the process for concentrating particles in a supension by gravity compression

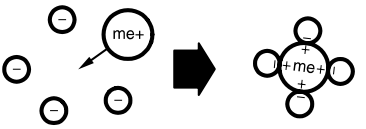
# Flocculation

All sedimentation technologies are related to particle size. One way of improving the settling speed generally is therefore to increase the size of the particles.

Fine particles can be connected together by coagulation or flocculation. The settling rate of the combined particles will be higher than that of each individual particle. This can also be applied prior to mechanical dewatering.

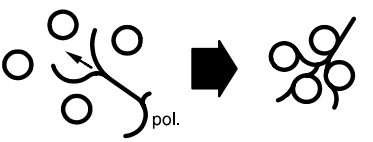
**Coagulation:** Surface charges are neutralized by addition of chemicals of opposite charge.

**Ex:** *$Fe^{+++}$ (iron sulphate)*
*$Al^{+++}$ (aluminium sulphate)*
*$Ca^{++}$ (lime)*




**A coagulated aggregate will reform after breaking (e.g. pumping).**

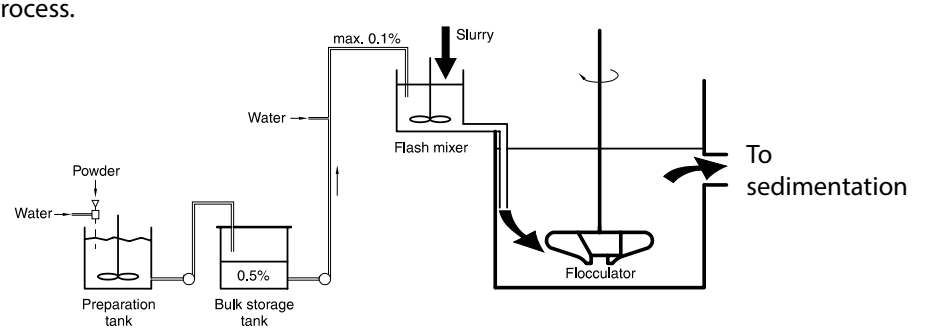
**Flocculation:** Polymers with molecule chains which physically link the particles together (mechanical bridging).




**A flocculated aggregate will not reform after breaking.**

## Flocculation system

A handling system is needed for flocculent utilisation. This comprises provision to mix, store and dilute the polymer. The dilute polymer is then mixed with the feed slurry and allowed to condition (or age) before a sedimentation or dewatering process.

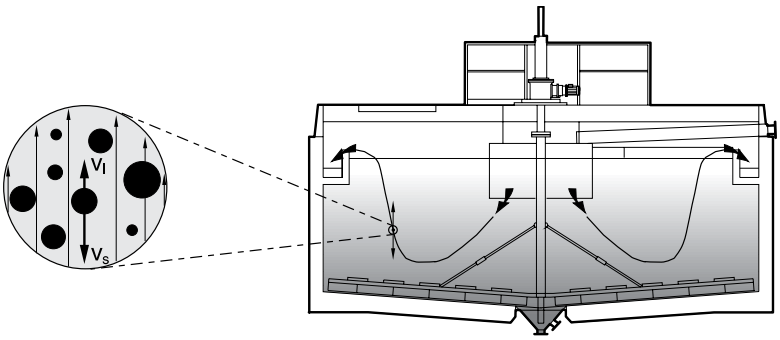



## Flocculation - addition and mixing time

| Application | Flocculant charge | Mixing time min | Addition rate g/m³ |
|---|---|---|---|
| Sand wash water | an- or non-ionic | 0.5 – 1 | 0.5 – 5 |
| Scrubber water (gas cleaning) | an-ionic | 0.5 – 2 | 0.5 – 2 |
| Coal tailings | non- and cat.ionic | 0.5 – 1 | 2.0 – 10 |
| Mineral tailings | an-ionic | 0.5 – 1 | 1.0 – 5 (40-80 g/t) |

## *Conventional clarifier*

Clarification is achieved when the liquid "upstream" velocity $V_L$ (rise rate) is lower than the sedimentation velocity of the solids $V_S$




## *Conventional clarifier – sizing*

Clarifier diameter is selected to give a suitable upstream velocity (m/h). Sizing is usally done using "Surface Load", meaning the volume of slurry $m^3/h$ fed per $m^2$ of clarifier surface. Typical surface loads are given below.



| Surface load material | Feed % | Surface load $m^3/m^2$, h | Surface load $ft^3/ft^2$, min | |
|---|---|---|---|---|
| Brine purification | 0.1 – 5 | 0.5 – 1.7 | 0.03 – 0.07 | |
| Coal refuse | 0.5 – 6 | 0.7 – 1.7 | 0.04 – 0.09 | |
| Clean coal fines | 1.0 – 5 | 1.0 – 1.9 | 0.06 – 0.10 | (with flocculation) |
| Heavy media magnetite | 20 – 30 | 6 – 7.5 | 0.32 – 0.41 | |
| Gas cleaning | 0.2 – 2 | 1.5 – 3.7 | 0.08 – 0.20 | (with flocculation) |
| Gypsum desulphurization | 1 – 3 | 1 – 2 | 0.06 – 0.12 | |
| Sand wash water | 1 – 5 | 0.3 – 1 | 0.02 – 0.06 | (without flocculation) |
| | 1 – 5 | 1 – 4 | 0.06 – 0.22 | (with flocculation) |
| Ore flotation tailings | 10 – 20 | 0.1 – 0.3 | 0.005 – 0.02 | (without flocculation) |
| | 10 – 20 | 0.5 – 1.5 | 0.03 – 0.08 | (with flocculation) |

**Example**

A wash water (100 $m^3/h$) coming from a sand operation needs to be clarified. Surface load is 0.5 $m^3/h/m^2$. Select clarifier diameter.

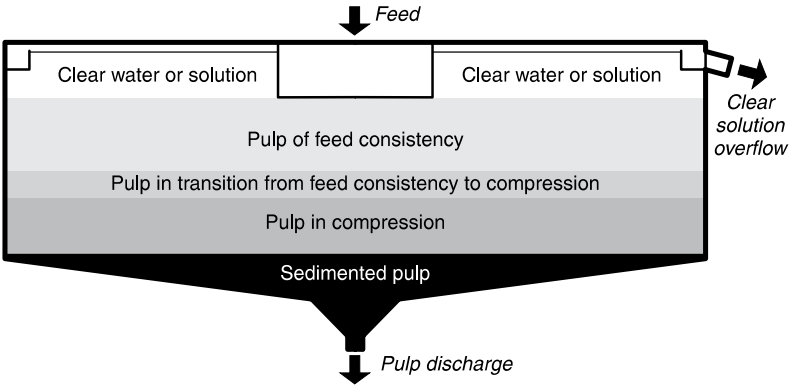
Required area is: 100/0.5 = 200 $m^2 = \frac{\pi d^2}{4} = 200$ where d is required diameter = 15.9.

Select a 16 m clarification tank!

Note! When thickening is also a critical part of the sedimentation process, the tank diameter has to be cross-checked with the diameter for thickener duty, see next page.

## Conventional thickener

Continuous thickening to give the required solids concentration in the underflow depends on balancing the volumetric solids flow rate at a critical concentration with the diameter of the thickener.




## Conventional thickeners – Sizing



Thickener selection is based upon the **unit area**, defined as $m^2$ of thickener area required per tph of solids. Typical figures for unit area are given below.

### Clarification/ thickening – cross checking (metric)

Clarification and thickening are process definitions. The equipment can be applied to both duties. If this is the case we have to select the tank area for each duty and select the largest of the two.

***Ex: Cu concentrate (k80= 80 µm), 10 t/h or 18m³/h***

Surface load (with flocculation) = 1.5 m/h

Unit area = 2 $m^2$/(t/h)

Clarification area = 18/ 1.5 = 12 $m^2$

Thickening area = 10x2 = 20 $m^2$

**Select a clarifier/thickener of 20$m^2$ , diameter 5 m.**

| Application | Feed % w/w | Underflow solids % w/w | Solids $m^2$ / t/h | Unit area $ft^2$/st x 24h | |
|---|---|---|---|---|---|
| Industrial minerals conc. | k80 150 µm | 15-25 | 50-60 | 3-6 | 1-3 |
| Industrial minerals conc. | k80 100 µm | 15-25 | 45-55 | 4-8 | 2-4 |
| Industrial minerals conc. | k80 50 µm | 15-25 | 40-50 | 6-12 | 1-5 |
| Industrial minerals conc. | k80 30 µm | 15-25 | 30-40 | 8-15 | 4-7 |
| Mineral tailings | k80 90 µm | 10-20 | 50-60 | 5-6 | 2-3 |
| Mineral tailings | k80 50 µm | 10-20 | 40-50 | 6-10 | 3-5 |
| Metallic mineral conc. | k80 130 µm | 20-30 | 60-70 | 1-2 | 0,5-1 |
| Metallic mineral conc. | k80 80µm | 20-30 | 55-65 | 2-3 | 1-2 |
| Metallic mineral conc. | k80 50 µm | 20-30 | 50-60 | 3-5 | 2-3 |
| Metallic mineral conc. | k80 30 µm | 20-30 | 45-55 | 4-7 | 2-3 |
| Metallic mineral conc. | k80 20 µm | 20-30 | 40-50 | 5 | 3-4 |

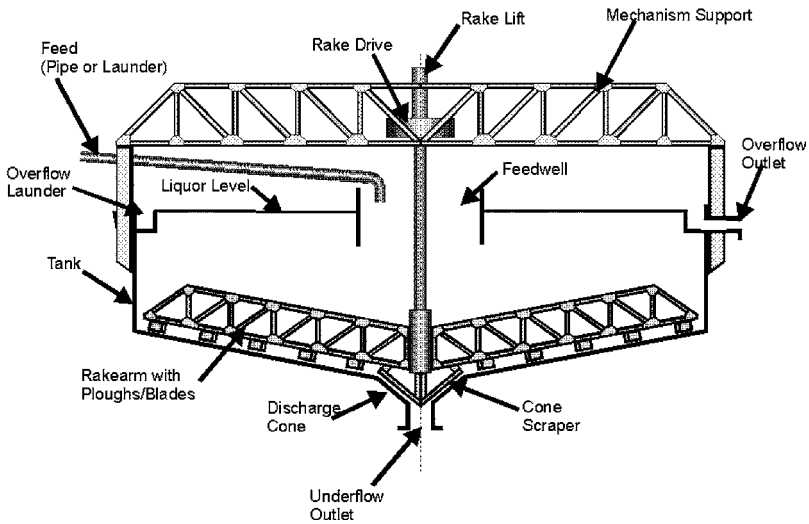
Heavy minerals are easier to treat. Mo and Zn are more difficult than i.e. Cu and Fe.

# *Conventional clarifier/thickener – Design**

## *Bridge type*

For smaller thickeners, up to 30 – 40 m diameter, the rakes and drive mechanism are supported on a bridge superstructure, which straddles the tank as shown.

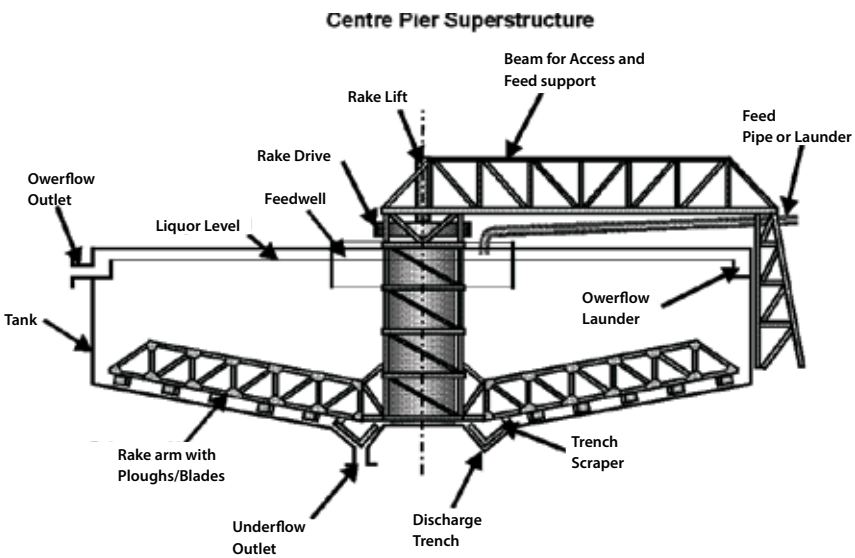
See data sheet 6:10.




## *Centre pier type*

For tanks over 30 – 40 m diameter a bridge structure will be impractical. The mechanism and rakes are therefore supported from a centre pier and the bridge is only used for access and to support feed pipe and launder.

See data sheet 6:11




### Design options

Up to 20 m elevated tank with underflow at ground level. Above 20 m tank at ground level with underflow in a tunnel.

*Contact Metso for further information about this product.

# *Conventional clarifier/thickener* – Drive system*

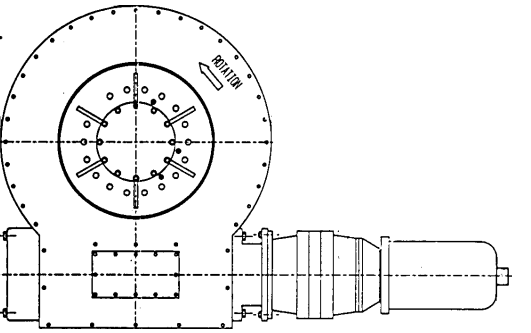
## *Drive mechanism*

For bridge and centre pier mounting.

Options with and without automatic rake lifting system.

Automatic torque monitoring

Slewing ring bearing to accommodate out of balance loads on rakes
Worm and wheel and multistage epicyclic gearbox drive




## *Conventional clarifier/thickener drives – torque definitions*

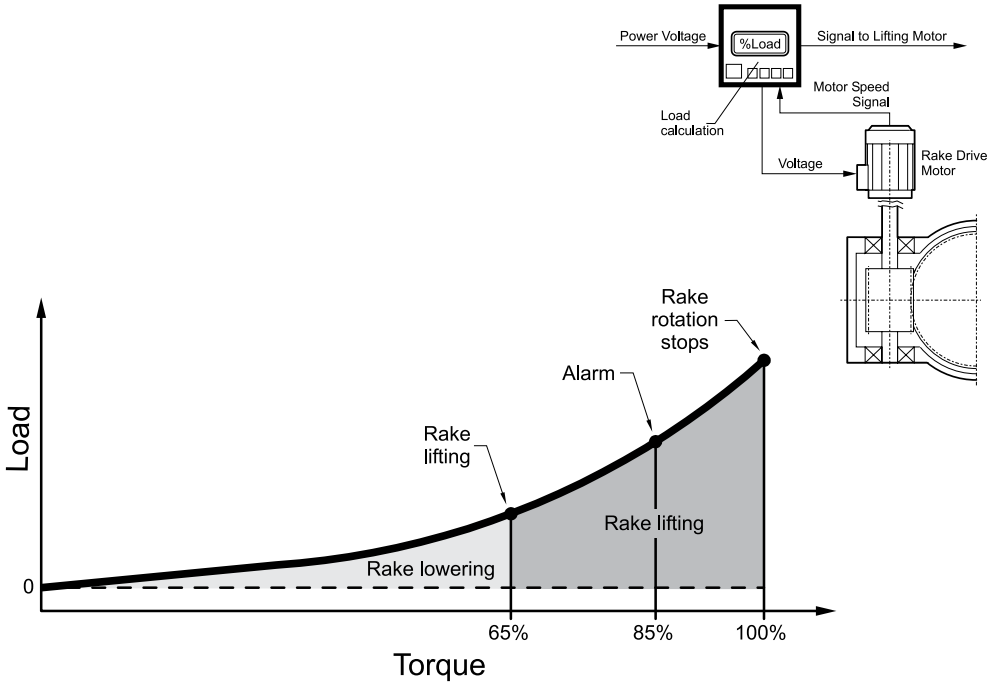
**10 year torque** The torque loading at which the drive head will have a calculated wear life of 10 years (also called equivalent torque)

**Cut out torque** Nominal 3000 hours wear life. App. 3 x "10 year torque". If the monitoring system detects a torque above this level the drive head will stop and a alarm will be raised in order to protect the rakes.

**Peak torque** Practical maximum torque. App. 2 x "cut out torque".

## *Conventional clarifier/thickener – control*

Torque is electronically detected and monitored. Increased torque is a sign that the solids loading in the thickener may be building up. This could indicate a process problem (change in feed, blocked underflow etc.). In all these cases rakes and drive have to be protected.




*Contact Metso for further information about this product.

# *Conventional clarifier/thickener* drive – Sizing*

## *Duty classification*

| | Very light duty | Light duty | Standard duty | Heavy duty | Extra heavy duty |
|---|---|---|---|---|---|
| **Separation/clarification classification** | **(1)** | **(2)** | **(3)** | **Thickening (4)** | **(5)** |
| **Solids loading** | | | | | |
| $m^2/t/h$ | >120 | 48 – 120 | 7 – 48 | 4 – 7 | <4 |
| $ft^2/st/day$ | >50 | 20 – 50 | 3 – 20 | 1.5 – 3 | <1.5 |
| **Underflow concentration** | | | | | |
| % solids by weight | <5 | 5 – 30 | 30 – 60 | >60 | >60 |
| **Specific gravity** | | | | | |
| dry solids | <2.5 | <2.5 | 2.0 – 3.5 | 3.0 – 4.5 | >4.0 |



## *Typical duties*

(1) Water treatment, river or lake water clarification, metallic hydroxides, brine clarification.

(2) Magnesium hydroxide, lime softening, brine softening.

(3) Copper tails, iron tails, coal refuse tails, coal, zinc or lead concentrates, clay, titanium oxide and phosphate tails.

(4) Uranium counter-current decantation (CCD), molybdenum sulphide.

(5) Iron oxide concentrates, magnetite, iron pellet feed, ilmenite.

Examine solids loading or specifications to determine whether duty is thickening or clarification. Proceed to relevant section to select drive head.

## *Typical drive head torque rating*

| Drive head size | kW/hp | Cut-out torque (Nm) | 10 year torque (Nm) |
|---|---|---|---|
| 10 | 1.5/2.0 | 32 000 | 10 000 |
| 12 | 1.5/2.0 | 45 000 | 17 000 |
| 14 | 1.5/2.0 | 72 000 | 26 000 |
| 17 | 3.0/4.0 | 120 000 | 45 000 |
| 20 | 3.0/4.0 | 190 000 | 65 000 |
| 24 | 4.0/4.0 | 310 000 | 112 000 |
| 28 | 5.5/7.4 | 450 000 | 164 000 |
| 32 | 5.5/7.4 | 610 000 | 225 000 |
| 36 | 11.0/14.8 | 800 000 | 301 000 |
| 40 | 11.0/14.8 | 1 100 000 | 397 000 |

*Contact Metso for further information about this product.

## *Clarifier drive selection*

Clarifiers, see duty page 6:8, operate with a low solids loading and drives are selected according to formula below

$$Tc = KxD^2$$

Tc = Process Cut Off torque (Nm)

K = Clarifier duty factor (see below)

D = Clarifier Diameter (m)

## *Duty factor*

| Clarifying application | Duty factor |
|---|---|
| Brine purification | 60 |
| Lime softening | 80 |
| Metal hydroxides | 150-200 |
| Lime sludge | 210 |
| Pulp and paper sludge | 250 |
| Metall works process water | 200-250 |
| Gas cleaning water | 350 |
| Heat treatment (metal) sludge | 440 |



Select a drive head from the" Drive Head Torque" values above, so that the specified "cut out torque" is greater then calculated Tc.

**Example:** Select a bridge mounted drive head for a 35 m diameter clarifier (no lift required). Application: lime sludge clarifying.

K factor = 210 giving a Tc = 210 x $35^2$ = 257 250 Nm. Select a drive head type BN 24, cut out torque 310 000 Nm.

## *Thickener drive selection*

Here we are calculating with Process Equivalent Torque (or 10 year torque).

$$Te = 256 \times D \times \sqrt{M}$$

Te = Process Equivalent Torque

D = Thickener diameter (m)

M = Solids in underflow (tph), see duty above

Select a drive head from the "Drive Head Torque" values above, so that the 10 year torque is greater than Te calculated above.

**Example:** Select a pier mounted drive head with a lift suitable for a 50 m diameter thickener handling an underflow of 130 tph of solids.

Te = 256 x 50 x $\sqrt{130}$ = 145 952 Nm. Select CL 28 drive head with a 10 year torque of 164 000 Nm.

## *Lamella or inclined plate sedimentation – Introduction*

Metso's lamella principle uses several parallel inclined plates to maximise the available area for any available floor area. In this way, the size and cost of the gravity settler can be minimised by matching the thickening and clarifying requirements more closely.

The two basic criteria for gravity settling equipment are good clarity of the over flow liquid and maximum density of the underflow solids discharge.

The area required to clarify a suspension is often greater than that needed for thickening.

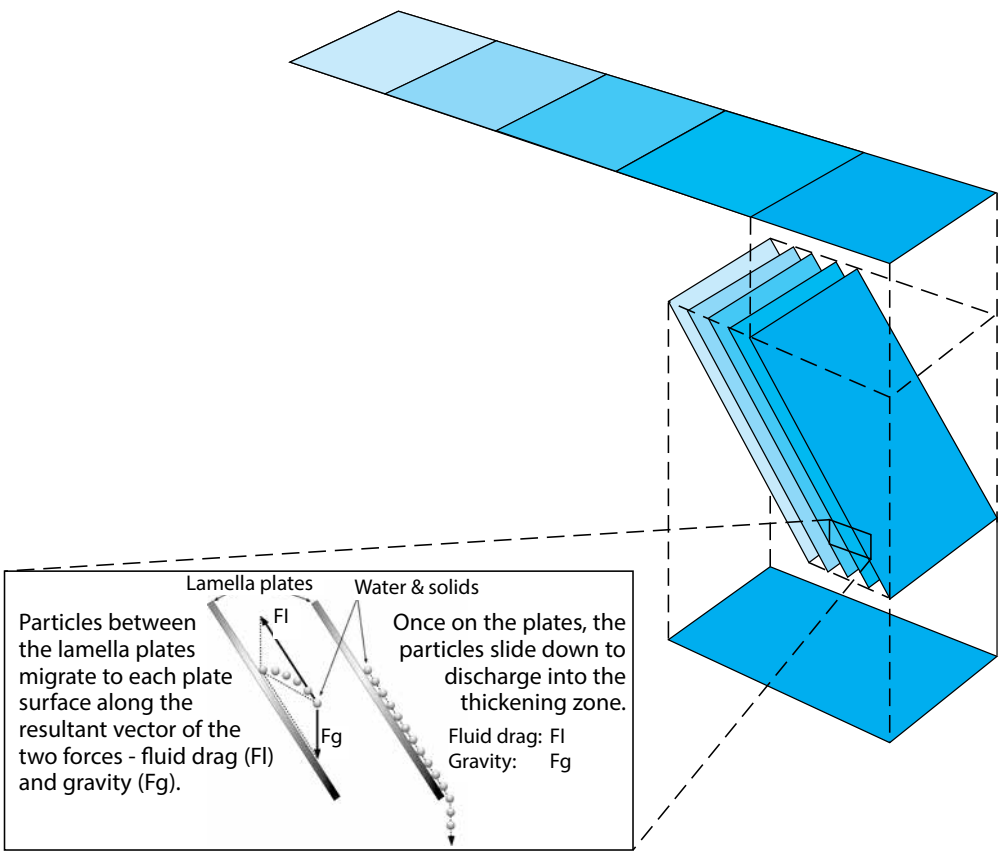
This means that in a cylindrical thickening tank, the lower section with rakes and drive mechanism can be oversized.

The lamella principle uses several parallel inclined plates to maximise the available settling area for any available floor area. In this way, the size and cost of the gravity settler can be minimized by matching the clarifying and thickening requirements more closely.

**Clarification is achieved** when upstream velocity is low enough to allow solids to report to the "Lamella plate".

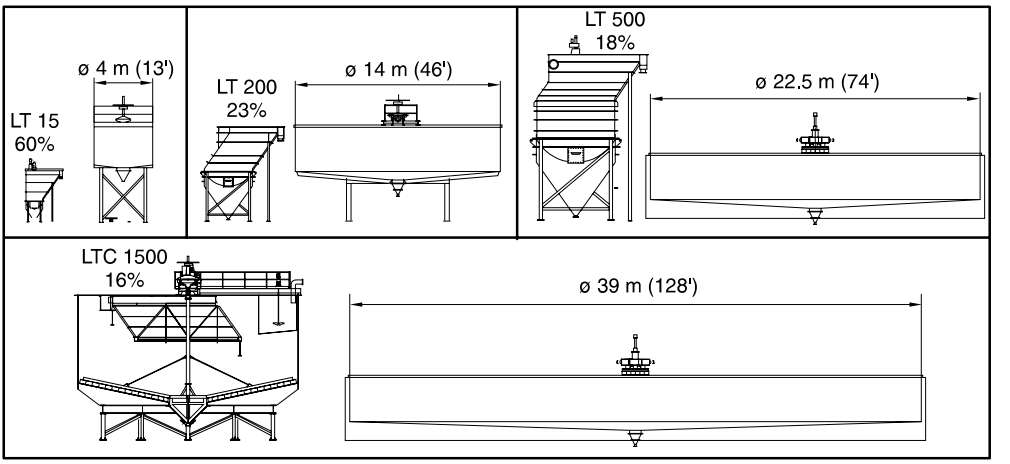
**Lamella thickening** is achieved as primary thickening on the lamella plates and secondary thickening and compression in the lower lamella tank.




Lamella plates
Water & solids
Fl
Fg
Particles between the lamella plates migrate to each plate surface along the resultant vector of the two forces - fluid drag (Fl) and gravity (Fg).
Once on the plates, the particles slide down to discharge into the thickening zone.
Fluid drag: Fl
Gravity: Fg

## *Lamella plates – principle*

The clarifiers and thickeners are utilising the "Lamella or Inclined Plate Principle" to perform sedimentation processes in much more compact equipment than would be possible using conventional techniques. Some typical comparisons of floor area requirements are given below (for clarification applications):






The Lamella concept offers many practical advantages:

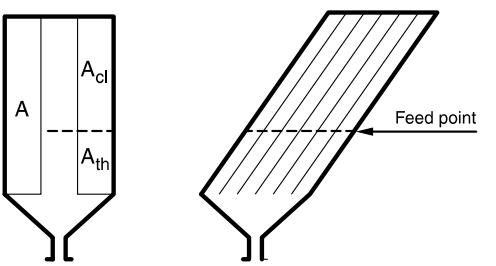
- Reduced plant area requirements
- Reduced retention time
- Possibility to optimize the ratio of clarification & thickening area
- Low heat losses – easy to insulate
- Low water losses due to evaporation – easy to cover
- Transport of the unit is more practical
- More suitable for indoor installation
- Quicker installation
- Easier to manufacture special designs (rubber lined, stainless steel etc.)
- Lower capital costs

There are limitations to the 'lamella concept' and in some of these cases conventional thickeners can be preferred. Examples are:

- High surface loads (above approx. 5.0 $m^3/m^2h$ (0.28 $ft^3/ft^2min$)
- Feeds with very high solids content / sludge volumes
- High froth content (flotation concentrates)

## *Lamella plates – function*

The area above the feed points is regarded as clarification area ($A^{cl}$), this can be up to 80% of the total plate area. The area beneath the feed point is thickening area ($A^{th}$), this can be up to 50% of the total plate area.



# *Inclined Plate Settler – IPS*

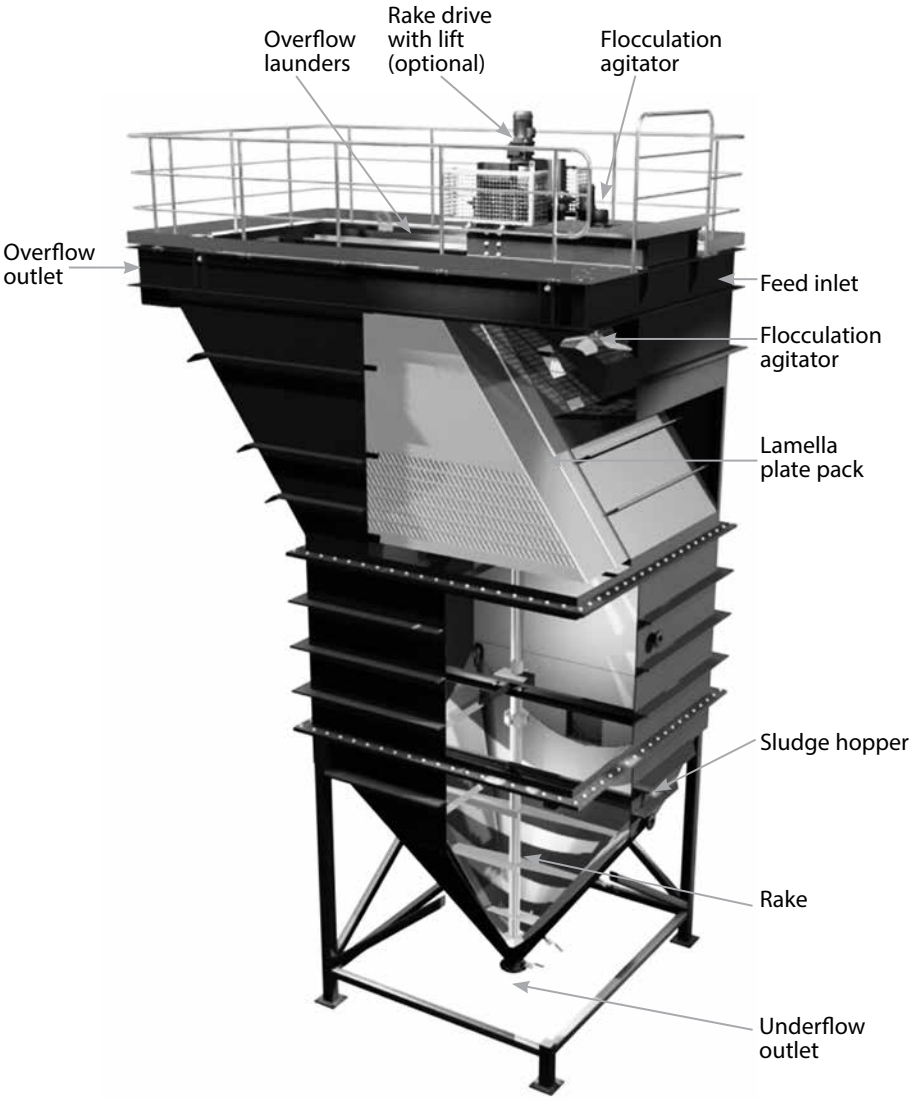
## *Design*

The inclined plate settler consists of two main components, the upper tank containing the lamella plates inclined at 55° and the lower conical or cylindrical sludge container.

The feed for the inclined plate settler enters through vertical chambers on either side of the lamella packs and passes into each plate gap through slotted feed ports. Clarification takes place above the suspension inlet so there is no mixing of the clarified fluid with the incoming feed.

Above each pack is a full-length overflow launder fitted with throttling holes to create a slight hydraulic back pressure on the incoming feed stream. This method of feed control guarantees equal distribution to all lamella chambers with minimum turbulence at the entry points.

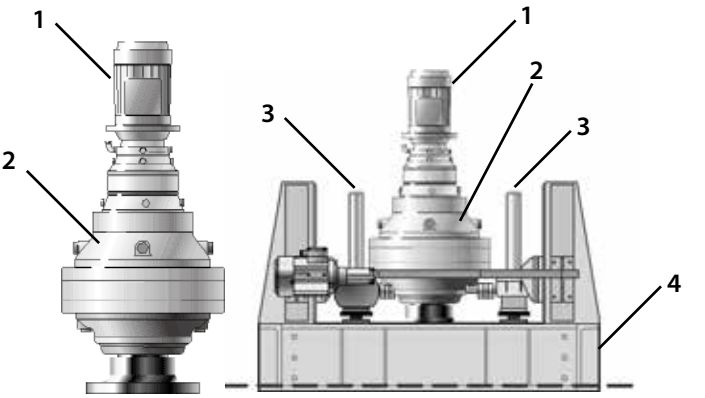
The solids settle onto and slide down each lamella plate to the sludge container where the solids are further thickened and compressed with the assistance of the raking system.



# *Inclined Plate Settler – Drives*

## *Design*

1. Gear motor
2. Planetary gear
3. Screw jack
4. Frame




## *Sizes*

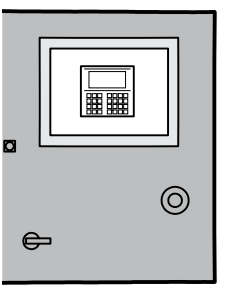
| Drive unit size | Max. operating torque (Nm) | (ft lbs) | Cut - out torque (Nm) | (ft lbs) | Power range (kW) | (hp) | Lifting capacity (kN) | (lbf) |
|---|---|---|---|---|---|---|---|---|
| SFL 02 | 2 000 | 1 475 | 2 700 | 1 990 | 0.18 – 0.75 | $^1/_4$ – 1 | 50 | 11 240 |
| SFL 05 | 5 000 | 3 690 | 6 750 | 5 000 | 0.37 – 2.2 | $^1/_2$ – 3 | 50 | 11 240 |
| SFL 10 | 10 000 | 7 380 | 13 500 | 9 956 | 0.37 – 5.5 | $^1/_2$ – 7$^1/_2$ | 50 | 11 240 |
| SFL 20 | 20 000 | 14 760 | 27 000 | 19 900 | 0.55 – 4.0 | $^3/_4$ – 5 | 50 | 11 240 |
| SFL 30 | 30 000 | 22 140 | 40 500 | 29 900 | 0.75 – 5.5 | 1 – 7$^1/_2$ | 50 | 11 240 |
| SFL 60 | 60 000 | 44 255 | 80 000 | 59 005 | 0.75 – 5.5 | 1 – 7$^1/_2$ | 100 | 22 480 |
| SFL 80 | 80 000 | 59 000 | 108 000 | 79 655 | 3-5,5 | 4-7,5 | 100 | 22 480 |
| SFL 100 | 100 000 | 73 755 | 135 000 | 99 550 | 3'-4 | 4-5,5 | 100 | 22 480 |
| SFL 130 | 130 000 | 95 885 | 175 500 | 129 440 | 4-5,5 | 5,5-7,5 | 150 | 33 720 |

## *Lifting sequences*

Definition: 100% load equal to max torque recommended by supplier.

| Load | Function |
|---|---|
| < 50% | Normal operation with rakes in lower position. |
| > 75% | Rakes are lifted until 100% load is reached. Rakes stay in upper position until 70% is reached, then lowering towards bottom position. |
| > 100% | Cut-out torque stops rotation of rakes. Lifting to the top position and alarm. Starts up normally from drive head control panel. |

## *Control panel*



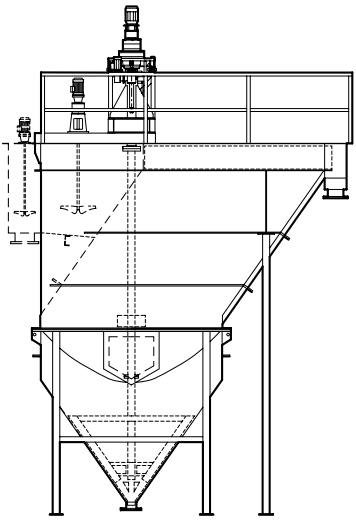
- PLC controlled
- Fully automatic incl. functions for:
  - Speed control of flocculator
  - Torque signal
  - Start and stop sequences
  - Alarm indications for levels, flows etc.
  - Control of underflow valve and pump

# *Inclined Plate Settler – Product range*

## *Type LT*

- Sizes up to 400 $m^2$ (4 305 $ft^2$) effective clarification area (500 $m^2$ total projected area)
- Effective also with coarser material
- Limited solids content in feed
- Extension of lower part as option
- Lifting device as option

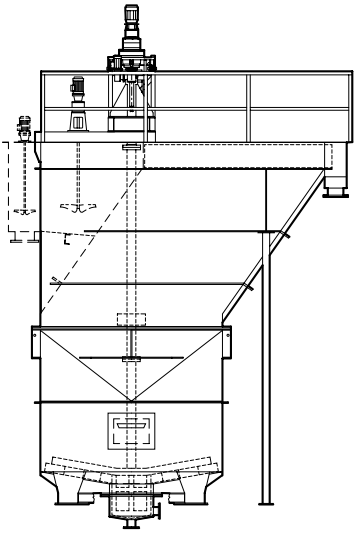
See also data sheet 6:19.



## *Type LTS*

- Sizes up to 400 $m^2$ (4 305 $ft^2$) effective clarification area (500 $m^2$ total projected area)
- Not suitable for coarse material (> 0.5-1 mm, 32 – 16 Mesh)
- Higher solids load
- Extension of lower part as option
- Lifting device as option

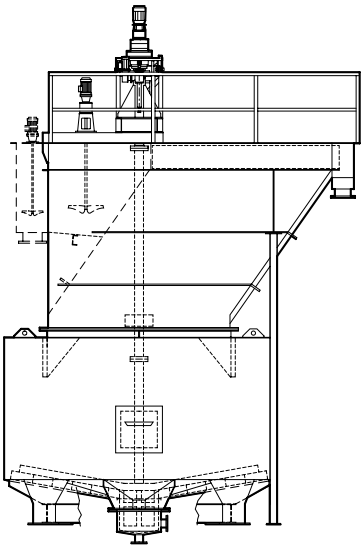
See also data sheet 6:20.



## *Type LTK*

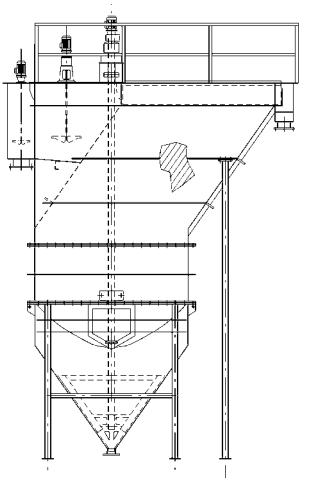
- Sizes up to 400 $m^2$ (4 305 $ft^2$) effective clarification area (500 $m^2$ total projected area)
- For higher solids load
- Used when storage and thickening is critical
- Extension of lower part as option
- Lifting device as standard

See also data sheet 6:21.



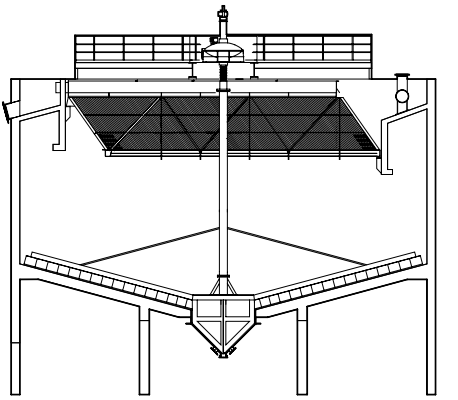
## *Type LT, LTS, LTK with extended tank*

- By lower tank extensions the volume can be increased giving better storage and improved thickening.



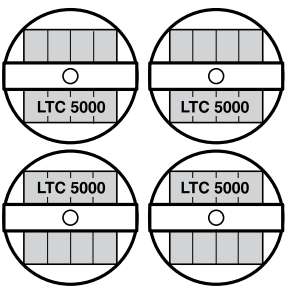
## *Type combi LTC*

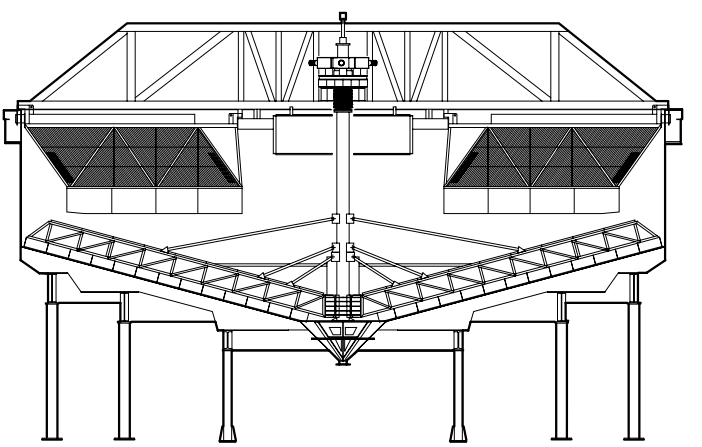
- Sizes up to tank dia 24 m (78.7 ft) = 400 $m^2$ (53 800 $ft^2$)
- For light and heavy duties
- High storage capacity
- Improved thickening
- Plate or concrete tank
- Conventional thickener drives



"Combi lamellas" built up by using lamella packs in circular tanks have principally no limitation in sizes.

From design point, however, max. practical area for each lamella unit is approx. 5 400 $m^2$. These sizes can then be combined in modules 5 400 $m^2$ + 5 400 $m^2$ + ... (58 125 $ft^2$ + 58 1250 $ft^2$ + ...)

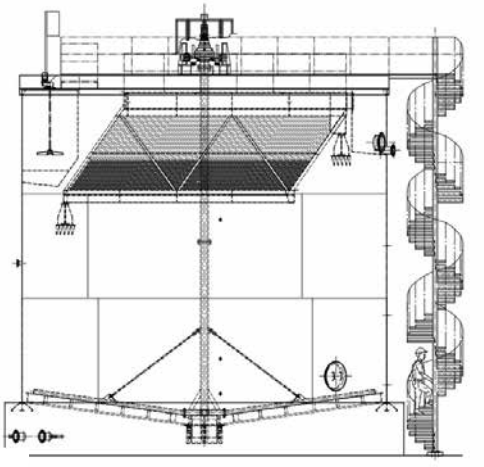


### *Type LTE*

- Sizes up to 1 140 $m^2$ (12 270 $ft^2$) projected area.
- Increased solids storage capacity, e.g. for installation prior to a batch process such as a filter press.

See also data sheet 6:22.

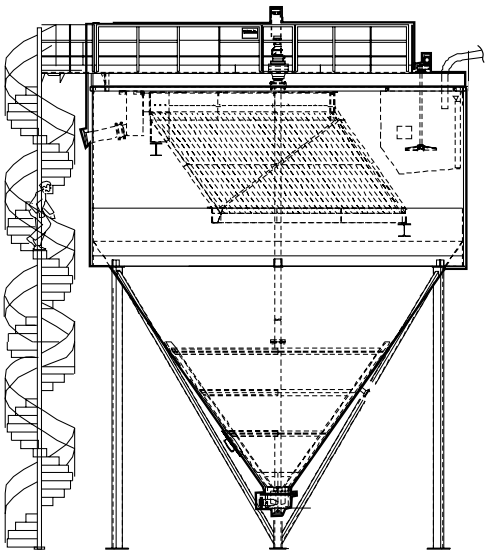




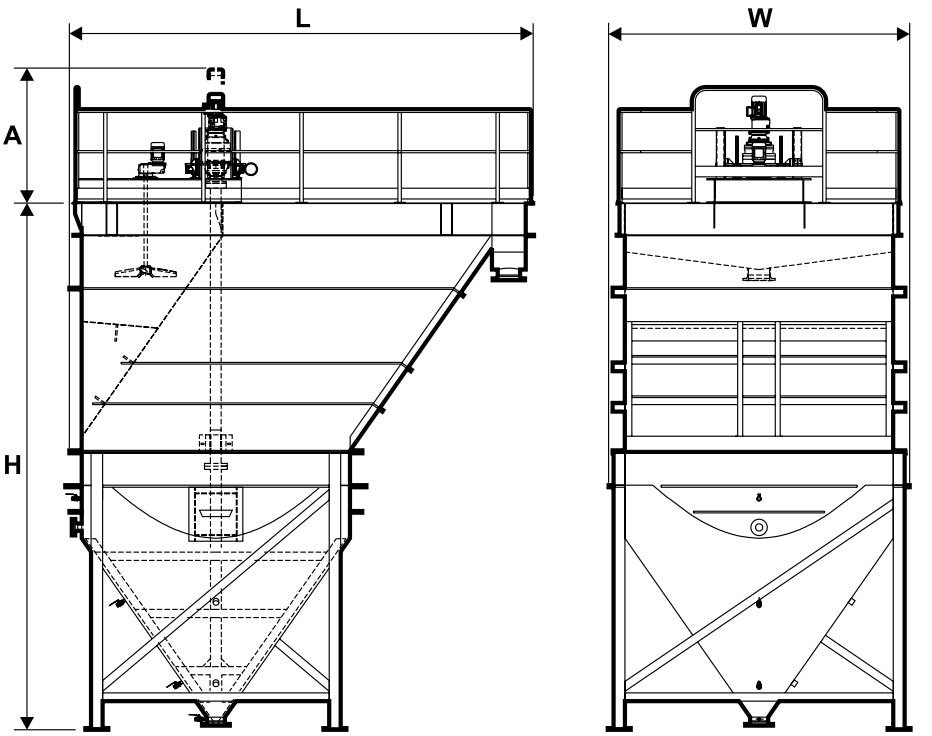
### *Type LTE/C*

- Similar to LTE above.
- Conical bottom for denser underflow.
- Improved access to underflow valves, pump and piping.

See also data sheet 6:23.

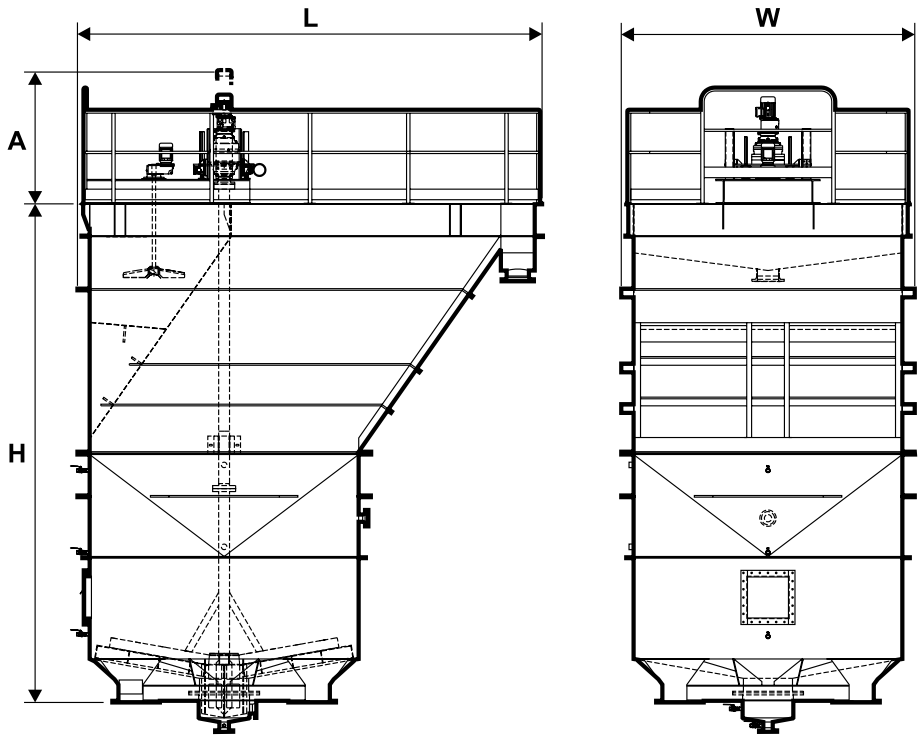


## *Inclined Plate Settler – LT*



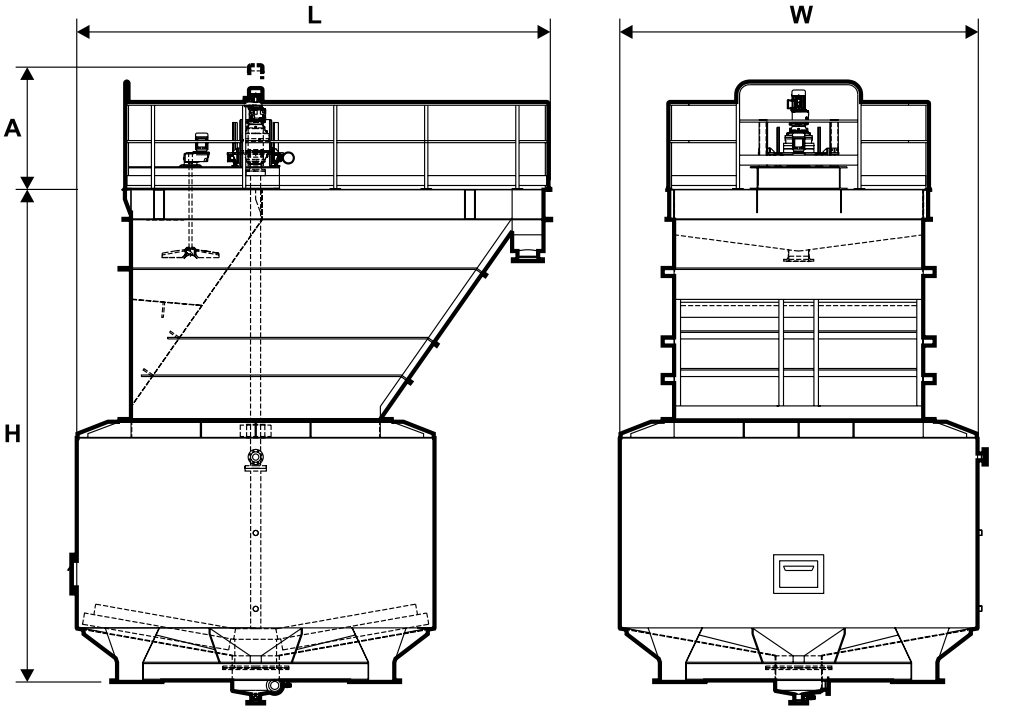

| Model | H (max) mm (ft) | L mm (ft) | W mm (ft) | A mm (ft) | Total volume $mm^3$ ($ft^3$) | Sludge volume $m^3$ ($ft^3$) | Flocculator volume $m^3$ ($ft^3$) | Weight empty kg (lbs) |
|---|---|---|---|---|---|---|---|---|
| LT 15 | 3 485 | 2 640 | 1 345 | 1 800 | 4.6 | 1.1 | 0.8 | 1 800 |
| | (11.4) | (8.7) | (4.4) | (5.9) | (162) | (39) | (28) | (3 968) |
| LT 30 | 4 300 | 3 430 | 1 830 | 1 800 | 9.2 | 2.3 | 0.8 | 3 500 |
| | (14.1) | (11.3) | (6.0) | (5.9) | (325) | (81) | (28) | (7 716) |
| LT 50 | 4 650 | 3 865 | 2 230 | 1 800 | 16.2 | 4.2 | 2.0 | 4 800 |
| | (15.3) | (12.7) | (7.3) | (5.9) | (572) | (148) | (71) | (10 582) |
| LT 100 | 5 400 | 4 510 | 2 870 | 1 800 | 28.7 | 9.4 | 3.0 | 7 800 |
| | (17.7) | (14.8) | (9.4) | (5.9) | (1 014) | (332) | (106) | (17 196) |
| LT 150 | 5 950 | 5 540 | 3 100 | 1 800 | 41.5 | 14.5 | 4.0 | 10 500 |
| | (19.5) | (18.2) | (10.2) | (5.9) | (1 466) | (512) | (141) | (23 149) |
| LT 200 | 6 500 | 5 740 | 3 690 | 1 800 | 54.6 | 18.8 | 5.0 | 13 200 |
| | (21.3) | (18.8) | (12.1) | (5.9) | (1 928) | (664) | (177) | (29 101) |
| LT 350 | 8 100 | 6 910 | 4 500 | 2 000 | 105.8 | 47.8 | 7.0 | 24 300 |
| | (26.6) | (22.7) | (14.8) | (6.6) | (3 736) | (1 688) | (247) | (53 572) |
| LT 500 | 8 630 | 7 810 | 5 780 | 2 000 | 160.8 | 72.8 | 8.0 | 39 500 |
| | (28.3) | (25.6) | (19.0) | (6.6) | (5 679) | (2 571) | (283) | (87 082) |

## *Inclined Plate Settler – LTS*




| Model | H (max) mm (ft) | L mm (ft) | W mm (ft) | A mm (ft) | Total volume $mm^3$ ($ft^3$) | Sludge volume $m^3$ ($ft^3$) | Flocculator volume $m^3$ ($ft^3$) | Weight empty kg (lbs) |
|---|---|---|---|---|---|---|---|---|
| LTS 15 | 3 750 | 2 640 | 1 345 | 1 800 | 5.2 | 1.7 | 0.8 | 2 000 |
| | (12.3) | (8.7) | (4.4) | (5.91) | (184) | (60) | (28) | (4 409) |
| LTS 30 | 4 620 | 3 430 | 1 830 | 1 800 | 11.1 | 4.2 | 0.8 | 3 700 |
| | (15.2) | (11.3) | (6.0) | (5.91) | (392) | (148) | (28) | (8 157) |
| LTS 50 | 4 700 | 3 865 | 2 230 | 1 800 | 18.6 | 6.6 | 2.0 | 5 100 |
| | (15.4) | (12.7) | (7.3) | (5.91) | (657) | (233) | (71) | (11 244) |
| LTS 100 | 5 130 | 4 510 | 2 870 | 1 800 | 32.5 | 13.2 | 3.0 | 8 600 |
| | (16.8) | (14.8) | (9.4) | (5.91) | (1 148) | (466) | (106) | (18 960) |
| LTS 150 | 5 300 | 5 540 | 3 100 | 1 800 | 45.8 | 18.8 | 4.0 | 11 300 |
| | (17.4) | (18.2) | (10.2) | (5.91) | (1 617) | (664) | (141) | (24 912) |
| LTS 200 | 6 100 | 5 740 | 3 690 | 1 800 | 61.8 | 26.0 | 5.0 | 15 800 |
| | (20.01) | (18.8) | (12.1) | (5.91) | (2 182) | (918) | (177) | (34 833) |
| LTS 350 | 6 200 | 6 910 | 4 500 | 2 000 | 114.0 | 56.0 | 7.0 | 23 000 |
| | (20.3) | (22.7) | (14.8) | (6.56) | (4 026) | (1 978) | (247) | (50 706) |
| LTS 500 | 6 400 | 7 810 | 5 780 | 2 000 | 153.0 | 65.0 | 8.0 | 36 000 |
| | (21.0) | (25.6) | (19.0) | (6.56) | (5 403) | (2 295) | (283) | (79 366) |

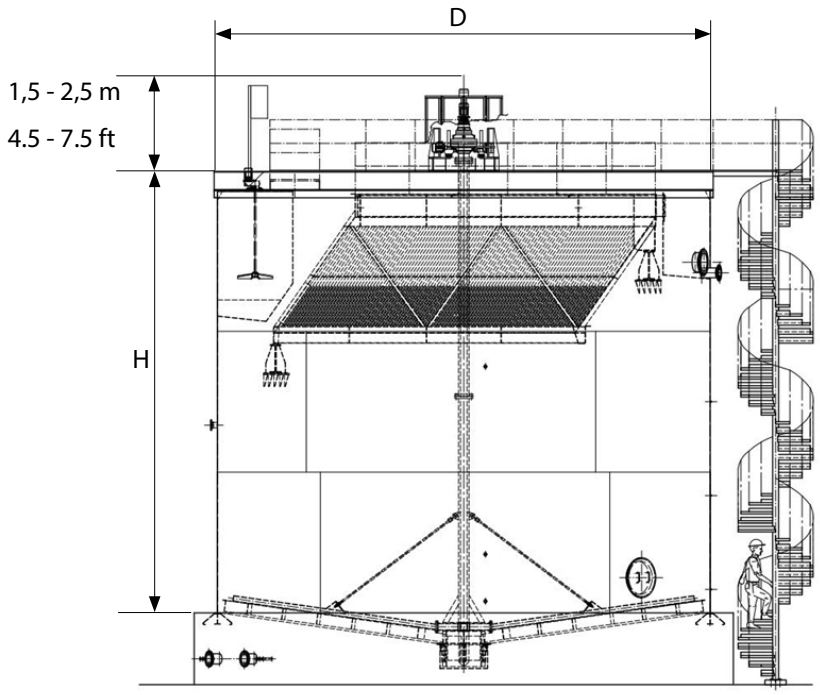
## *Inclined Plate Settler – LTK*





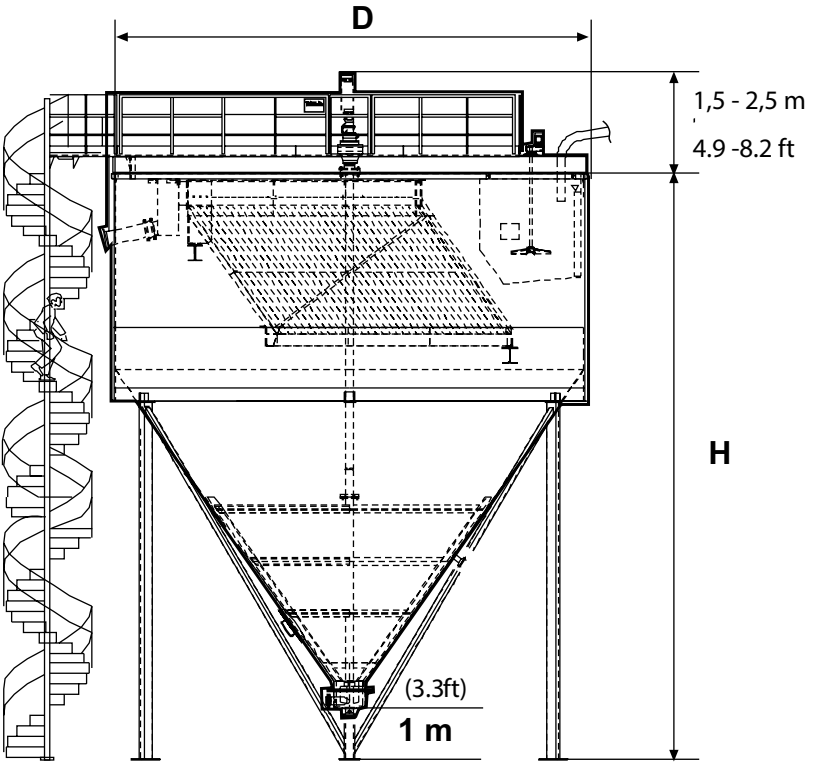

| Model | H mm (ft) | L mm (ft) | W mm (ft) | A mm (ft) | Total volume $mm^3$ ($ft^3$) | Sludge volume $m^3$ ($ft^3$) | Flocculator volume $m^3$ ($ft^3$) | Weight empty kg (lbs) |
|---|---|---|---|---|---|---|---|---|
| LTK 15 | 5 100 | 2 795 | 1 610 | 1 800 | 8.0 | 4.5 | 0.8 | 2 200 |
| | (16.7) | (9.2) | (5.3) | (5.9) | (283) | (159) | (28) | (4 850) |
| LTK 30 | 4 550 | 3 690 | 2 310 | 1 800 | 14.5 | 7.6 | 0.8 | 4 500 |
| | (14.9) | (12.11) | (7.6) | (5.9) | (512) | (268) | (28) | (9 921) |
| LTK 50 | 4 800 | 4 170 | 2 810 | 1 800 | 23.5 | 11.5 | 2.0 | 6 200 |
| | (15.7) | (13.7) | (9.2) | (5.9) | (830) | (406) | (71) | (13 669) |
| LTK 100 | 5 390 | 5 020 | 3 715 | 1 800 | 45.5 | 26.2 | 3.0 | 10 100 |
| | (17.7) | (16.5) | (12.2) | (5.9) | (1 607) | (925) | (106) | (22 267) |
| LTK 150 | 5 800 | 5 885 | 4 490 | 1 800 | 61.0 | 34.0 | 4.0 | 13 000 |
| | (19.0) | (19.3) | (14.7) | (5.9) | (2 154) | (1 201) | (141) | (28 660) |
| LTK 200 | 6 500 | 6 235 | 4 715 | 1 800 | 87.0 | 51.2 | 5.0 | 16 500 |
| | (21.3) | (20.6) | (15.5) | (5.9) | (3 072) | (1 808) | (177) | (36 376) |
| LTK 350 | 6 930 | 7 485 | 6 220 | 2 000 | 143.0 | 85.0 | 7.0 | 26 500 |
| | (22.7) | (24.6) | (20.4) | (6.6) | (5 050) | (3 002) | (247) | (58 422) |
| LTK 500 | 6 940 | 8 705 | 7 520 | 2 000 | 200.0 | 112.0 | 8.0 | 46 500 |
| | (22,8) | (28,6) | (24,7) | (6,6) | (7 063) | (3 955) | (283) | (102 515) |

## *Inclined Plate Settler – LTE*



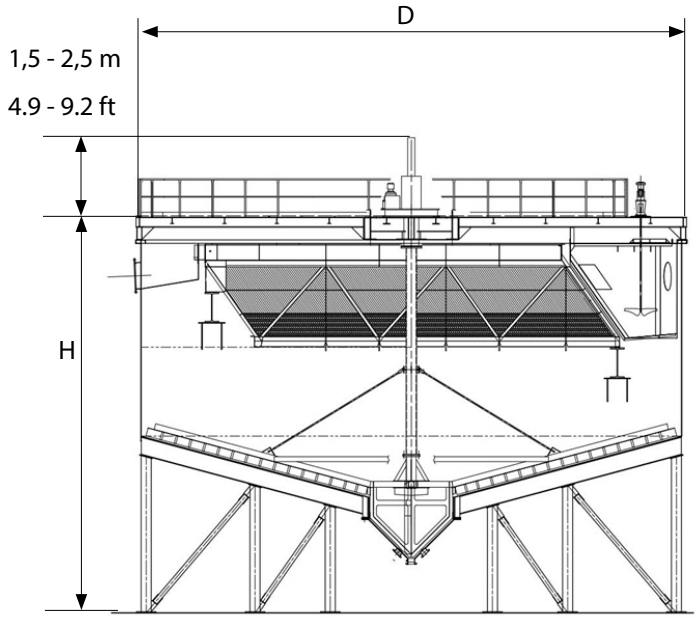

| Model | Settling area $m^2$ ($ft^2$) | Tank dia (D) mm (ft) | Tank height (H) mm (ft) | Sludge volume $m^3$ ($ft^3$) | Total volume $m^3$ ($ft^3$) |
|---|---|---|---|---|---|
| LTE 220-6.3 | 220 (2 386) | 6 300 (20.7) | 6 000 (19.7) | 86 (3 040) | 192 (6 780) |
| | | | 9 000 (29.5) | 179 (6 320) | 285 (10 065) |
| LTE 275-7.1 | 275 (2 960) | 7 100 (23.3) | 6 000 (19.7) | 110 (3 885) | 244 (8 629) |
| | | | 9 000 (29.5) | 228 (8 050) | 363 (12 820) |
| LTE 440-8.3 | 440 (4736) | 8 300 (27.0) | 6 000 (19.7) | 151 (5 335) | 335 (11 830) |
| | | | 9 000 (29.5) | 314 (11 090) | 497 (17 550) |
| | | | 12 000 (39.4) | 476 (16 810) | 660 (23 310) |
| LTE 550-9.0 | 550 (5 920) | 9 000 (29.5) | 6 000 (19.7) | 179 (6 320) | 395 (13 950) |
| | | | 9 000 (29.5) | 370 (13 065) | 586 (20 695) |
| | | | 12 000 (39.4) | 561 (19 810) | 777 (27 440) |
| LTE800-10.5 | 800 (8 611) | 10 500 (34.4) | 6 000 (19.7) | 246 (8 690) | 541 (19 105) |
| | | | 9 000 (29.5) | 506 (17 870) | 801 (28 290) |
| | | | 12 000 (39.4) | 766 (27 050) | 1 060 (37 435) |
| LTE 1140 | 1 140 (12 270) | 12 000 (39.4) | 6 000 (19.7) | 326 (11 510) | 710 (25 0705) |
| | | | 9 000 (29.5) | 665 (23 480) | 1 050 (37 080) |
| | | | 12 000 (39.4) | 1004 (35 4555) | 1 389 (49 050) |

## *Inclined Plate Settler – LTE/C*




| Model | Settling area $m^2$ ($ft^2$) | Tank dia (D) mm (ft) | Tank height (H) mm (ft) | Sludge volume $m^3$ ($ft^3$) | Total volume $m^3$ ($ft^3$) |
|---|---|---|---|---|---|
| LTE/C 220-6.3 | 220 (2 368) | 6 300 (20.7) | 8 500 (27.9) | 66 (2 3301) | 172 (6 075) |
| LTE/C 275-7.1 | 275 (2 960) | 7 100 (23.3) | 10 000 (33.0) | 91 (3 215) | 225 (7 945) |
| LTE/C 440-8.3 | 440 (4 736) | 8 300 (27.2) | 11 000 (36.0) | 140 (4 945) | 324 (11 440) |
| LTE/C 550-9.0 | 550 (5 920) | 9 000 (29.5) | 11 500 (37.7) | 175 (6 180) | 391 (13 810) |
| LTE/C 800-10.5 | 800 (8 611) | 10 500 (34.4) | 12 500 (41.0) | 269 (9 500) | 563 (19 880) |
| LTE/C 1040-12 | 1 140 (11 194) | 12 000 (39.4) | 13 500 (44.3) | 392 (13 845) | 776 (27 405) |

## *Inclined Plate Settler – LTC*






| *Model | Settling area $m^2$ ($ft^2$) | Tank dia (D) mm (ft) | Tank height height (H) mm (ft) | **Sludge volume $m^3$ ($ft^3$) | Total volume $m^3$ ($ft^3$) |
|---|---|---|---|---|---|
| LTC 1140 | 1 140 (12 270) | 12 000 (39.4) | Min. 8 050 (26,4) | 345 (12 185) | 710 (25 075) |
| LTC 1500 | 1 500 (161 145) | 12 500 (41.0) | Min. 8 400 (27.6) | 330 (11 655) | 715 (25 250) |
| LTC 1500 | 1 500 (161 145) | 15 000 (49.2) | Min. 9 465 (31.1) | 620 (21 895) | 1180 (41 670) |
| LTC 1900/2200 | 1 900/2 200 (20 450/23 680) | 15 000 (49.2) | Min. 9 465 (31.1) | 620 (21 895) | 1180 (41 670) |
| LTC 2300/2700 | 2 300/2 700 (24 755/29 060) | 16 500 (54.1) | Min. 8 400 (28) | 705 ( 24 895) | 1345 (47 500) |
| LTC 2300/2700 | 2 300/2 700 (24 755/29 060) | 16 500 (54.1) | Min. 10 100 (33.1) | 760 (26 840) | 1445 (51 030) |
| LTC 3450 | 3 450/37 135 | 18 000 (59.1) | Min. 10 305 (33.8) | 900 (31 785) | 1 735 (61 270) |
| LTC 3450 | 3 450/37 135 | 18 000 (59.1) | Min. 8 600 (28.2) | 875 (30 900) | 1 635 (57 740) |
| LTC 4300 | 4 300 (46 285) | 21 000 (98.9) | Min. 9 485 (31.1) | 1 170 (41 320) | 2 320 (81 930) |
| LTC 5250/5400 | 5 250/5 400 (56 510/58 125) | 24 000 (78.7) | Min. 10 515 (34.5) | 1 720 (60 740) | 3 095 (109 300) |
| LTC 5250/5400 | 5 250/5 400 (56 510/58 125) | 24 000 (78.7) | Min. 9 050 (29.7) | 1590 (56 150) | 2 970 (104 885) |

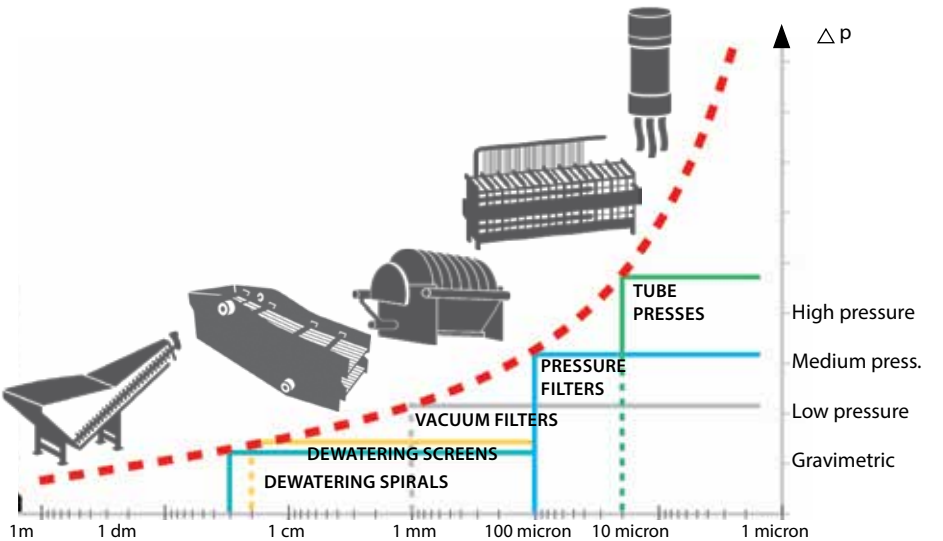
*All models except LTC 1500 with tank dia 12 500 mm has integrated flocculator chamber.

**Sludge volume from tank bottom to lamella pack lower end = max allowable.

## *Mechanical dewatering – Introduction*

Mechanical dewatering means mechanical removal of liquids from a slurry to obtain the solids in a suitable form and/or recovery of a valueable liquid for:

- Further processing
- Transportation
- Agglomeration
- Disposal
- Recovery of valuable liquids




## *Mechanical dewatering – Methods and products*

**Gravimetric dewatering**

- Dewatering spirals (not covered)
- Dewatering screens
- Dewatering wheels (not covered)

**Low pressure dewatering**

- Drum vacuum filters
- Belt drum vacuum filters
- Top feed vacuum filters
- Disc vacuum filters (not covered)
- Horizontal belt vacuum filters (not covered)

**Medium pressure dewatering**

- Air pressure filters (compression and through-blow)

**High pressure dewatering**

- Tube presses (compression and air-purged)

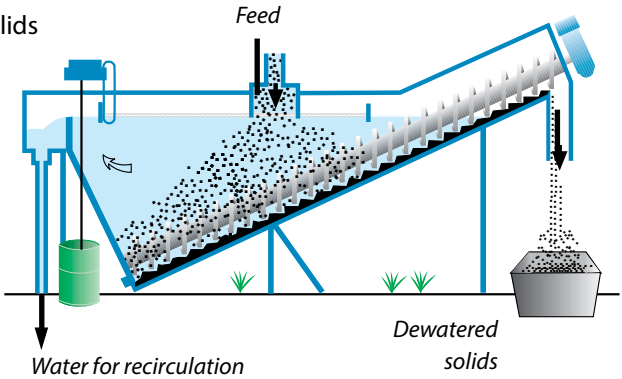
## Gravimetric dewatering

When the particles in a slurry are too coarse for the capillary forces to "trap" the water, the use of gravity is enough to remove the water and give at least transportable solids.

## Spiral dewaterer

Spiral dewaterer for coarse solids
Typical application is scales removal in steel mill.

- Feed usually up to 2% solids w/w.
- 10 – 1 500 $m^3$/h (44-6 600 USGPM)
- Remaining moisture 5-20% w/w.
- Large sedimentation pool
- Oil skimmer as option




See also data sheet 6:27.

### Spiral dewaterer – Sizes

| Model | Pool area ($m^2$) | Pool area ($ft^2$) |
|---|---|---|
| SDC45-3 | 3 | 32 |
| SDC45-5 | 5 | 54 |
| SDC45-7 | 7 | 75 |
| SDC60-10 | 10 | 108 |
| SDC60-20 | 20 | 215 |
| SDC60-40 | 40 | 430 |
| SD60-100* | 100 | 1 075 |
| SDC60-40/100** | 40-100 | 430-1075 |
| SDC60-200 | 200 | 2050 |

* With lamella plate ** With variable lamella plate package

### Spiral dewaterer – Sizing

Required pool area = Volume / surface load

Regarding surface loads m/h ($m^3/m^2$ and hour) see page 6:3

**For preliminary sizing use:**

10 – 20 m/h (0,55 - 1,1 ft/min)

**Ex: Cooling water from continuous casting must be treated for recirculation. Particles up to about 100 µm are accepted in the cooling water spray nozzles.**

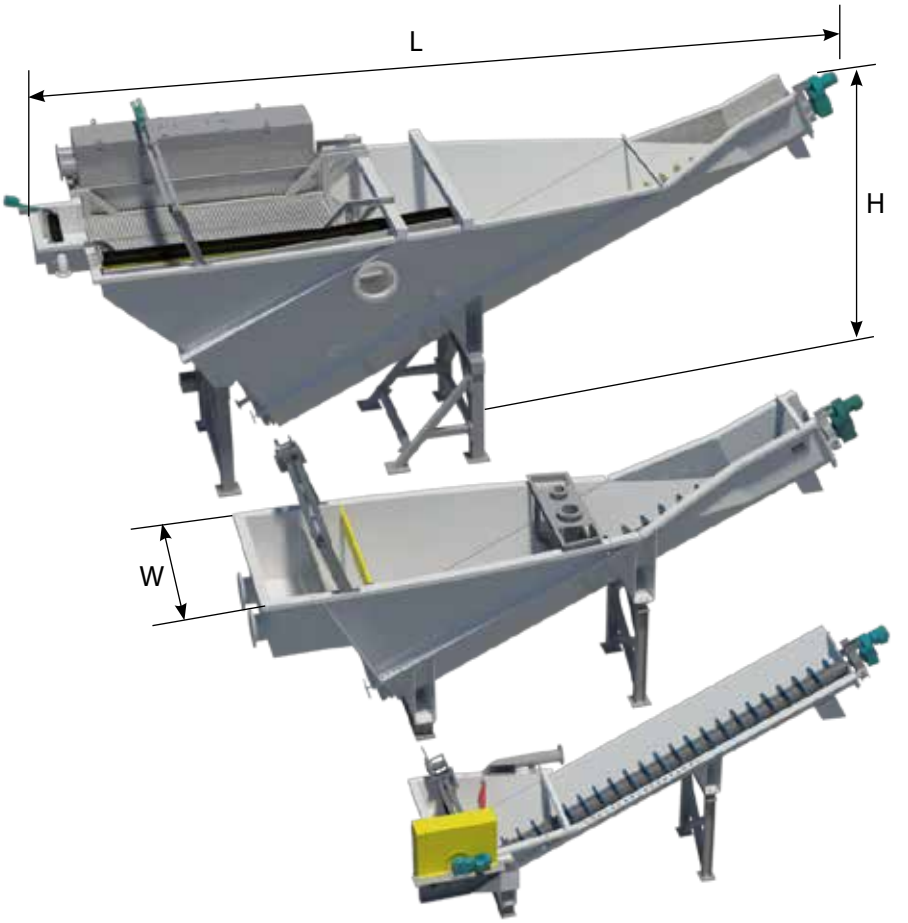
*The flow is 800 $m^3$/h with 2 g/l mill scale.*

*Surface load of approx. 20 $m^3/m^2$ x h will give required separation.*

*Pool area: 800 / 20 =40 $m^2$*

*Select spiral dewaterer SDC 60 - 40*

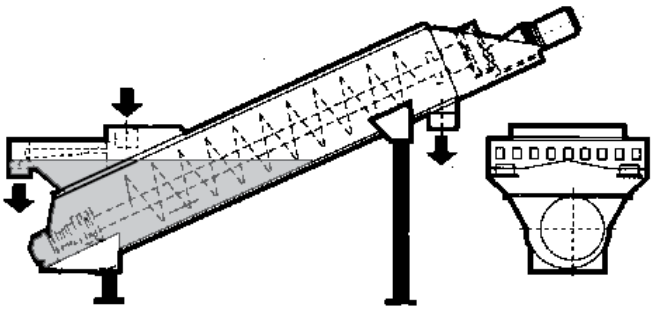
## *Spiral dewaterer*




| Model | H mm (inch) | L mm (inch) | W mm (inch) | Power kW/hp | Weight nom. flooded ton (empty) | Tank volume $m^3$ ($ft^3$) |
|---|---|---|---|---|---|---|
| SDC45-3 | 3450 (136) | 6700 (264) | 2000 (79) | 1.5 (2) | 2,3 | 1.4/1.8 (49/64) |
| SDC45-5 | 3450 (136) | 6700 (264) | 2150 (85) | 1.5 (2) | 2,5 | 3,5/4,2 (123/148) |
| SDC45-7 | 3450 (136) | 6700 (264) | 2200 (87) | 1.5 (2) | 2,7 | 5,9 /6,6 (208/233) |
| SDC60-10 | 4550 (179) | 9200 (362) | 2620 (103) | 1.5 (2) | 6,5 | 10/13 (353/459) |
| SDC60-20 | 5550 (218) | 11550 (455) | 3520 (139) | 3 (4) | 9,5 | 25/30 (883/1059) |
| SDC60-40 | 6450 (254) | 14100 (555) | 4880 (192) | 4 (4) | 17 | 60/70 (2119/2472) |
| SDC60-100 | 6450 (254) | 14100 (555) | 4880 (192) | 4 (5) | 18,5 | 60/70 (2119/2472) |
| SDC60-40/100 | 6450 (254) | 14100 (555) | 4880 (192) | 4 (5) | 19 | 60/70 (2119/2472) |
| SDC60-200 | 6450 (254) | 14100 (555) | 4880 (192) | 4 (5) | 20 | 60/70 (2119/2472) |

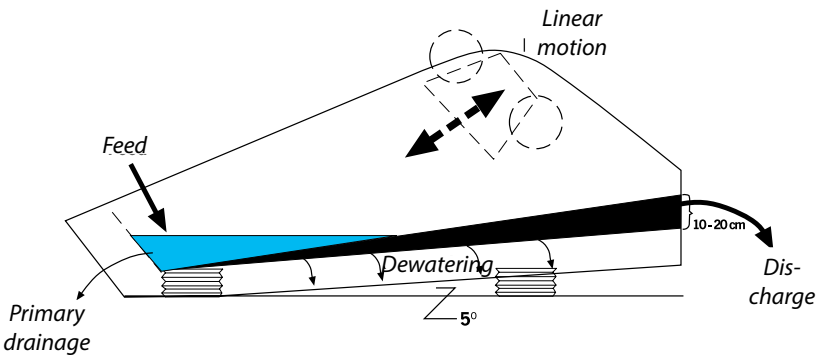
## *Sand screw**

This is a simpler version of the spiral dewaterer mainly used for natural sand. These sands are normally classified (particles below 10 – 50 micron are removed) meaning that the sedimentation pool is very limited compared to the spiral dewaterer.



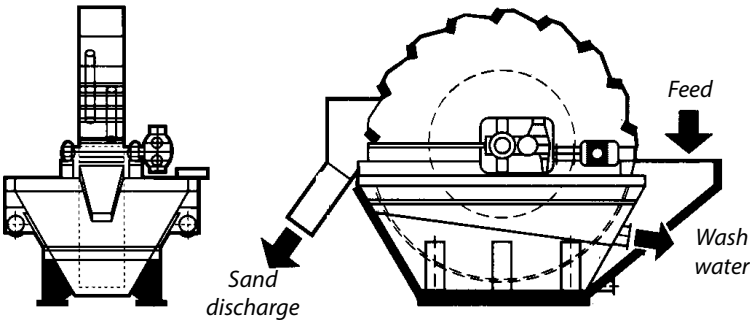
## *Dewatering screen**

This is a version of a screen in linear motion moving the solids upwards on an inclined plane at an inclination of 5°. Dewatering takes place in the moving sand bed. Only for sand, coal or other deslimed solids.




## *Dewatering wheel**

The dewatering wheel is mainly used in dredging of natural sand and gravel. The machine has a simple water draining arrangement at the sand removal buckets. Therefore the water content can be reduced down to 15-18 % $H_2O$ by weight even if the feed contains certain fines. The pool is limited meaning that the machine is sensitive to high volume flows.

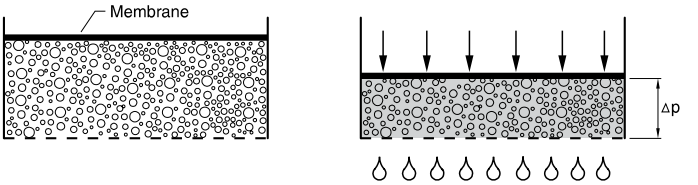



*Not available from Metso.

# Mechanical dewatering by pressure – Introduction

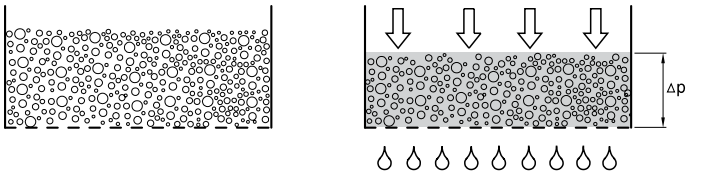
As particles get finer the resistance against removing water increases. Gravity dewatering can no longer be used. Pressure has to be applied.
By creating a differential pressure Δp across a cake of solids, liquid can be removed by

## Compression




"Dewatering by compression means replacing the liquid in a cake with particles"

## Through blow




"Dewatering by through-blow means replacing the water in a cake with air"

For ***vacuum filters*** *air-through blow* is used

For ***vertical plate pressure filters*** either compression or a combination of compression and air through-blow is used

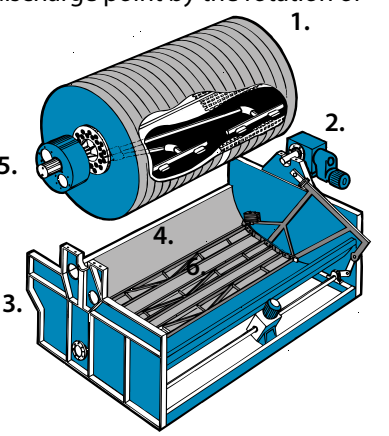
For ***tube presses*** either compression or a combination of compression and air-purge (air through blow) is used. The Tube Press also enables cake washing.

*Cake wash can be applied to any of these filters*

# Drum vacuum filters

Vacuum filtration is the simplest form of "through blow" dewatering. A pressure differential created by a vacuum applied to the inside of the filter drum causes air to flow through the filter cake thereby displacing the contained water. The solids are retained on a filter cloth and are carried to discharge point by the rotation of the drum.

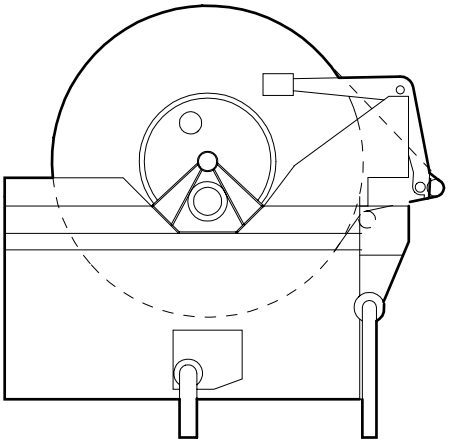
## Drum filter

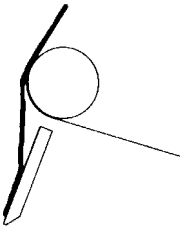



1. **Drum** – filter cloth mounted on segment grids. Internal drainage pipes.
2. **Drum drive** – variable speed
3. **Support frame**
4. **Tank**
5. **Vacuum head** – seal arrangement to connect rotating drum to stationary vacuum piping
6. **Agitator** – to suspend solid particles in tank

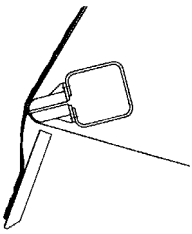
### *Belt drum filter**

The belt discharge drum filter is similar to the standard drum version except that the cloth is separated from the drum and allowed to pass over a discharge system.
This design allows cloth washing and is preferred for dewatering of slurries containing fine particles which produce a filter cake that is sticky and difficult to discharge.
Three cake discharge options are available.

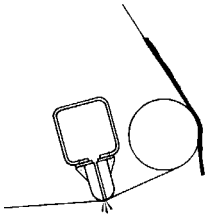




*Break roller*



*Air knife*

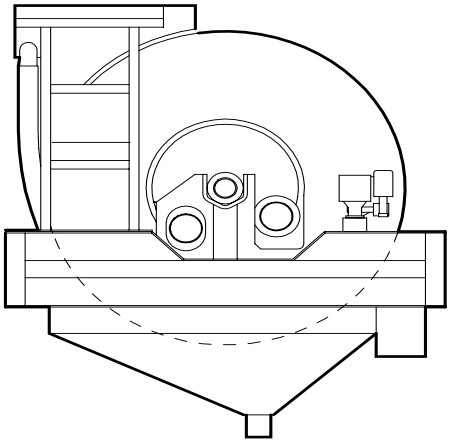


*Break roller and air knife*

*Contact Metso for further information about this product.

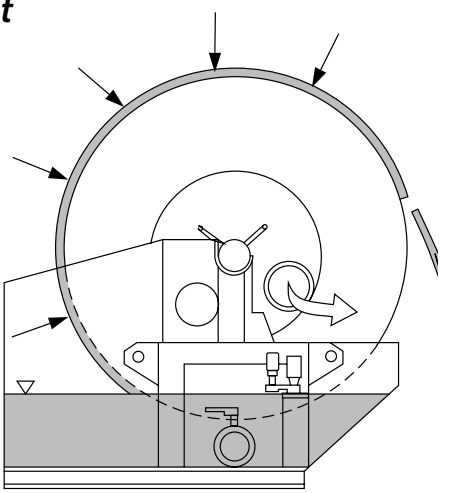
### *Top feed drum filter**

A top feed drum filter is designed to dewater de-slimed slurries containing coarser particles.
The top feed principle promotes segregation of the coarser particles forming a "pre-coat" on the filter cloth thereby increasing filtration rate.



*Contact Metso for further information about this product.

## *Vacuum filters – Vacuum requirement*



### *Principle*

By evacuating the air inside the filters dewatering can be achieved by air "through-blow".

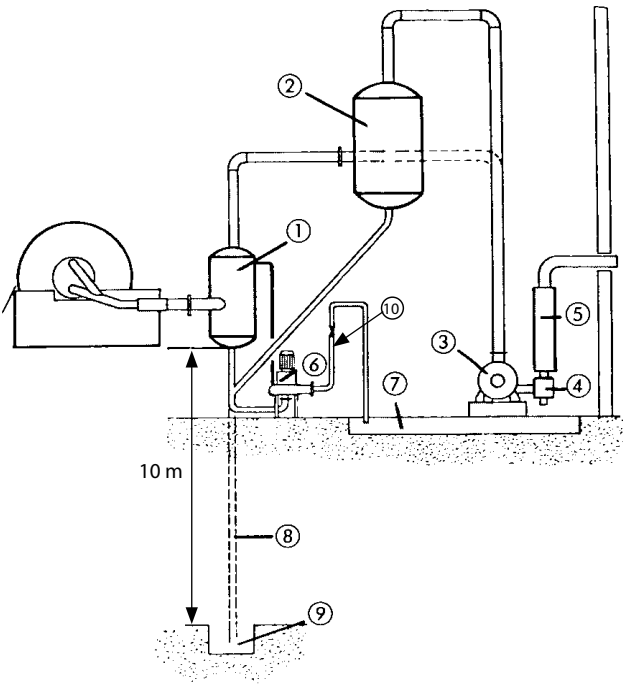
**Vacuum requirement** is calculated as the volume of thinned air per effective filter surface area per minute.

**Thinned air** volume is volume at actual reduced pressure.

**Free air** volume (used for sizing of compressors) is the volume at normal atmospheric pressure.

## *Vacuum plant – Arrangement*






1. Vacuum receiver
2. Moisture trap*
3. Vacuum pump
4. Liquid separator
5. Silencer
6. Filtrate pump
7. Floor drain

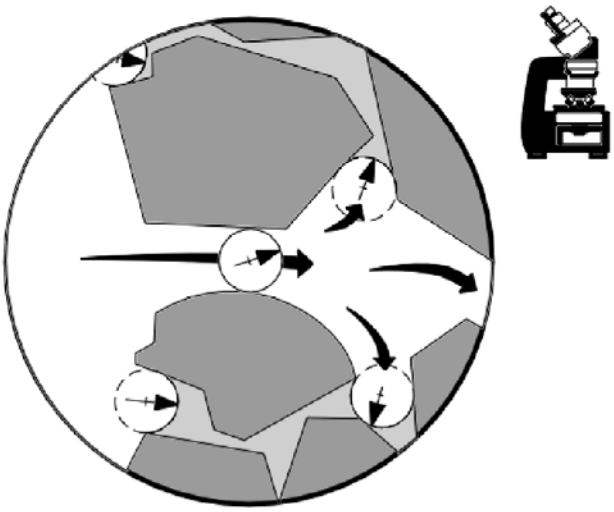
*For plants without filtrate pump also:*

8. Drain line from vacuum tank (barometric leg)
9. Water lock
10. Non-return valve

* Normally used for aggressive filtrates only.

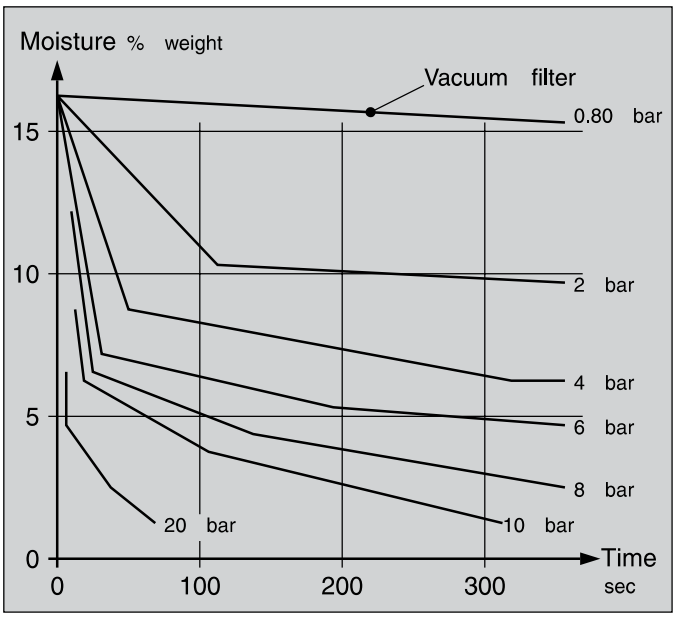
## *Vertical plate pressure filter – Introduction*

The pressure filter model VPA is of "medium pressure" type operating in the pressure range of 6 –10 bar. The machine mainly relies on the "air through blow" dewatering concept, whereby water is displaced by air as it passes through a filter cake.



*Air penetration through a pore system*

The driving force of this filtration method is the pressure differential across the cake. A higher pressure drop will give a faster dewatering rate and a lower residual moisture, as smaller voids are emptied from liquid.



## *Vertical plate pressure filter – Design*

- **VPA = V**ertical **P**ressure Filter **A**ir through blow
- Lightweight polypropylene filter plates are mounted on a bolted steel frame and are moved by hydraulic cylinders
- Adjacent "filter and compression" plates form a filtration chamber. The filter cloths hang between each pair of plates. Rubber membranes are protected by the filter cloth thereby reducing wear.
- By mounting the filter on a load cell system the filtration cycle is monitored and controlled.
- Chambers are top fed for optimum filling. Two sided filtration speeds up the "filling" cycle.
- Openings for pulp, water and air are generously dimensioned to reduce energy losses and wear
- Service and maintenance requirements are low. The VPA design facilitates easy cloth changing.
- Air blow pressure 5 – 8 bar (73 –116 psi). Membrane pressure 8 – 10 bar (116-145 psi)



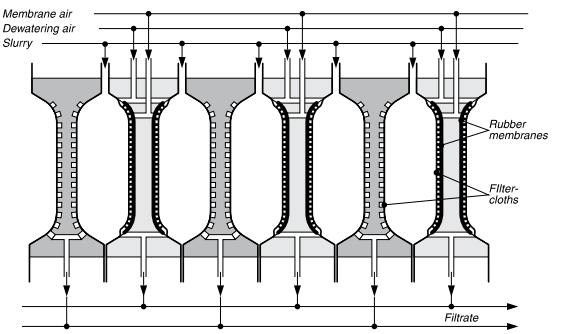
## *Pressure filter VPA – Operation*

### *Pretreatment*

For optional results of filter operation the pulp fed to the machine should be as high in solids as possible.

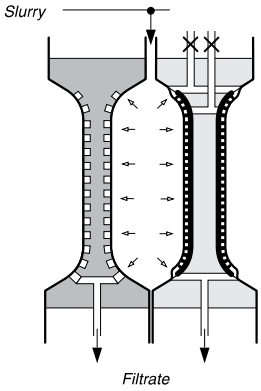
### *Dewatering cycle*

**Start position**



**Step 1 – Filtration**

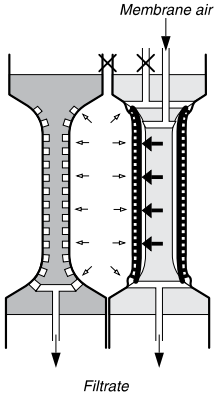
Slurry is pumped into the filter chambers and the filtrate is expelled.




**Step 2 – Compression**

in which the rubber membrane in each chamber is activated and the filter cake is compressed (densely packed).

**Dense cake formation avoids unnecessary leakage of air during subsequent drying.**

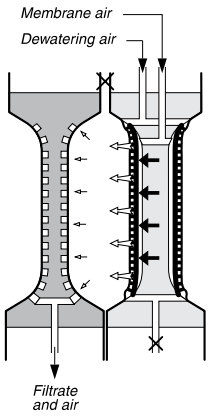





**Step 3 – Air drying**

Compressed air is forced through the filter cake driving out more liquid.

**The rubber membrane remains activated throughout this cycle to counteract cracking of the shrinking cake.**




These are the dewatering steps. In cases when throughblow is not applicable and filter is used for compression, only step 1 and 2 are used.

## *Service cycle*

**In addition to the above dewatering steps the complete process includes a number of so called service steps.**

**Step 4 – 9 – Service cycle**

4. Opening  cake discharge doors
5. Opening the filter, discharging the filter cakes
6. Vibrating the filter cloths (discharge control)
7. Closing the cake discharge doors
8. Rinsing the filter cloths
9. Closing the filter

## *Pressure filter – Sizes*

**The VPA pressure filter is available in 3 chamber sizes:**

VPA 10 with chamber dimensions (outer) of 10 x 10 dm (max 40 chambers)

VPA 15 with chamber dimensions (outer) of 15 x 15 dm (max 60 chambers)

VPA 20 with chamber dimensions (outer) of 20 x 20 dm (max 54 chambers)

## *Pressure filter VPA – Chamber data*

### *Chamber area (working area)*

Chamber area VPA 10 = 0.65 $m^2$/chamber (7 $ft^2$/chamber)

Chamber area VPA 15 = 1.70 $m^2$/chamber (18 $ft^2$/chamber)

Chamber area VPA 20 = 3.90 $m^2$/chamber (42 $ft^2$/chamber)

**Filtration area** = 2 x chamber area (each chamber has double cloths and filtering takes place on both sides).

**Drying (or through blow) area** = chamber area (air enters from one side).



### *Chamber volume*

VPA 1030 (32 mm chamber depth) = 20.0 litre (5 USG)

VPA 1040 (42 mm chamber depth) = 25.0 litre (7 USG)

VPA 1530 (32 mm chamber depth) = 55.0 litre (15 USG)

VPA 1540 (42 mm chamber depth) = 68.0 litre (18 USG)

VPA 2040 (42 mm chamber depth) = 169 litre (45 USG)

VPA 2050 (53 mm chamber depth) = 205 litre (54 USG)

### *Chamber depth*

For VPA 10 and VPA 15 two chamber depths are available.

32 mm ($1^1/_4$") for fine particle dewatering (long cycle time)

42 mm ($1^3/_5$") for medium particle dewatering (normal cycle time)

VPA 20 can be supplied with two chamber depths 42 and 53 mm.
($1^3/_5$", $2^1/_{10}$")

## *Pressure filter VPA – Nomenclature*

**VPA 1040-20** = Pressure filter type VPA with chamber dimensions 10 x 10 dm, chamber depth 40 mm and number of chambers 20.

See also data sheet 6:48 - 6:50.

# *Pressure filter VPA – Sizing*

We are using the cycle method:

## *1. Cake bulk weights*

Specific dry weight of the filter cake inside each chamber is called the **cake bulk weight** (kg/liter or lb/ft$^3$)

Approximate cake bulk weights ($\rho_{cake}$) usually about 60% of specific gravity.

| Material | kg/dm$^3$ | lb/ft$^3$ |
|---|---|---|
| Cu-conc (80%-45 micron) | 2.2 | 137 |
| Pb-conc (80%-40 micron) | 3.1 | 193 |
| Zn-conc (80%-30 micron) | 2.1 | 131 |
| Magnetite conc. (80%-x micron) | 3.0 | 187 |
| Coal | 0.9 | 56 |
| Chalk | 1.3 | 81 |

## *2. Plant capacity*

By dividing the required throughput S (t/h or lb/h) with cake bulk weight the required cake volume per hour is obtained. $V=S/\rho_{cake}$

## *3. Cycle time*

Is calculated as the sum of

- Filtration
- Compression
- Washing
- Through blow (drying)
- Service time (discharge, washing and closing)

**Total cycle time t (min/cycle)**

Number of cycles per hour n = 60/t.

**Approximate cycle times (min)**

| Application | $k_{80}$ | t min |
|---|---|---|
| Cu-conc | 50 | 7 |
| | 15 | 11 |
| Pb-conc | 40 | 7 |
| | 20 | 9 |
| Zn-conc | 40 | 7 |
| | 20 | 9 |
| Magnetite | 40 | 5 |
| Flotation tailings | 36 | 8 - 20 |

## *4. Filter volume*

The required volume per cycle equals required filter volume.

Filter volume = V / n = (S x 1000 x t) / ($\rho_{cake}$ x 60) liter

**Ex. A zinc concentrate should be dewatered to 8% $H_2O$.**

The capacity is 12 t/h (dry solids) and $k_{80}$ 35 mm.

1. Cake bulk weight $\rho_{cake}$ = 2.1 (from table).
2. Plant capacity V = 12 / 2.1 = 5.7 $m^3$/h
3. Cycle time t = 8 min. (estimated from table).
   Cycles per hour n = 60 / 8 = 7.5
4. Filter volume V / n = (5.7 x 1 000) / 7.5 = 760 l
   ***Select VPA-1040-32 (800 l)***

## *Pressure filter VPA - Moisture in filter cake*

Following approximate moistures in the dewatered cakes (using 6 bar air blow pressure) can be expected.

| Material | Moisture % $H_2O$ by weight |
|---|---|
| Cu-conc medium (80% - 45 µm) | 7.0 - 8.0 |
| Cu-conc fine (80% - 15 µm) | 9.0 - 11.0 |
| Pb-conc medium (80% - 40 µm) | 5.0 - 6.0 |
| Zn-conc. medium (80% - 30 µm) | 8.0 - 9.0 |
| Pyrite conc. coarse (80% - 60 µm) | 5.0 - 6.0 |
| Hematite conc. medium (80% - 40 µm) | 10 - 12 |
| Magnetite medium (80% - 40 µm) | 6.0 - 8.0 |
| Calcite conc. fine (80% - 8 µm) | 12.0 -15.0 |
| Mineral tailings (0 - 500 µm) | 15 - 20 |

## *Pressure filter VPA - Compressor sizing*

Compressed air for pressure filters are calculated as
**"Normal cubic meters of free air at normal temperature and atmospheric pressure required per $m^2$ of filter area per minute".**
Requirement of compressed air (throughblow) at end of drying

| Particle size | Compressed air ($Nm^3/m^2/min$) | ($ft^3/ft^2/min$) |
|---|---|---|
| Mineral concentrates 80 % passing 30 µm | 0.4 | 1.3 |
| Mineral concentrates 80 % passing 40 µm | 0.5 | 1.6 |
| Mineral concentrates 80 % passing 50 µm | 0.6 | 2.0 |
| Mineral concentrates 80 % passing 80 µm | 0.9 | 2.9 |
| Mineral tailings 0-500 µm | 0.4 | 1.3 |

**Ex. A fine Cu-conc requires 0.5 $Nm^3/m^2/min$ for drying to requested moisture. A filter of type VPA 15-40 will be used.**

*Air consumption 0.5 x 40 x 1.7 = 34 $Nm^3$ per min.*
*"Select a suitable compressor", see below.*

*Atlas Copco 38.7 $Nm^3$/min. installed power 250 kW (50 Hz).*

*Atlas Copco 37.8 $Nm^3$/min. installed power 285 kW (60 Hz).*

## *Pressure filter VPA – Compressor power*

(Table below shows Atlas Copco medium pressure water-cooled two-stage screw compressors (oil free), unload pressure 8 bar (50 Hz) 8.6 bar (60 Hz).

| Model | Capacity | | Installed power | | Model | Capacity | | Installed power | |
|---|---|---|---|---|---|---|---|---|---|
| (50 Hz) | ($Nm^3$/min) | ($ft^2$/min) | (kW) | (hp) | (60 Hz) | ($Nm^3$/min) | ($ft^3$/min) | (kW) | (hp) |
| ZR3-50 | 11.0 | 389 | 75 | 100 | ZR3-60 | 12.7 | 449 | 104 | 139 |
| 51 | 13.6 | 480 | 90 | 120 | 61 | 15.8 | 558 | 127 | 170 |
| 52 | 16.6 | 586 | 110 | 147 | 62 | 19.1 | 675 | 148 | 198 |
| 53 | 19.5 | 689 | 132 | 177 | 63 | 22.5 | 795 | 180 | 241 |
| 54 | 22.4 | 791 | 160 | 215 | ZR4-60 | 24.6 | 869 | 184 | 246 |
| ZR4-50 | 25.1 | 887 | 160 | 215 | 61 | 30.8 | 1 088 | 230 | 308 |
| 51 | 30.7 | 1 085 | 200 | 268 | 62 | 37.8 | 1 335 | 285 | 382 |
| 52 | 38.7 | 1 367 | 250 | 335 | ZR5-60 | 44.6 | 1 576 | 285 | 382 |
| ZR5-50 | 46.4 | 1 639 | 315 | 422 | 61 | 51.0 | 1 802 | 360 | 483 |
| 51 | 50.3 | 1 777 | 315 | 422 | 62 | 56.6 | 2 000 | 405 | 543 |
| 52 | 61.3 | 2 166 | 400 | 536 | 63 | 60.9 | 2 152 | 405 | 543 |
| 53 | 68.9 | 2 434 | 450 | 603 | ZR6-60 | 76.2 | 2 692 | – | – |
| ZR6-50 | 79.8 | 2 819 | – | – | 61 | 88.2 | 3 116 | – | – |
| 51 | 100.5 | 3 551 | – | – | 62 | 102.0 | 3 604 | – | – |
| 52 | 112.5 | 3 975 | – | – | 63 | 102.8 | 3 632 | – | – |

## *Pressure filter VPA – Feed pump selection* (guidance only)

For **VPA 10**, choose **4"** slurry pump

For **VPA 15**, choose **6"** slurry pump

For **VPA 20**, choose **8"** slurry pump

## *Pressure filter VPA - Feed pump power* (approximate)

| | | |
|---|---|---|
| VPA 10-8 to VPA 10-20 | 55 kW | 74 hp |
| VPA 10-22 to VPA 10-40 | 75 kW | 100 hp |
| VPA 15-10 to VPA 15-20 | 75 kW | 100 hp |
| VPA 15-22 to VPA 15-60 | 132 kW | 177 hp |
| VPA 20-10 to VPA 20-20 | 160 kW | 215 hp |
| VPA 20-22 to VPA 20-60 | 200 kW | 268 hp |

## *Pressure filter VPA - Product system*

In a complete dewatering plant the compressed air filter is only one part of what we call the VPA system.

The VPA system consists of the following equipment:

**Thickener** to feed the filter with correct pulp density. (1)

**Buffer tank** for deaeration and pulp density control prior to pump feeding. (2)

**Slurry pump** for feeding during the filtration cycle. (3)

**Valves** for pulp, water and air. (4)

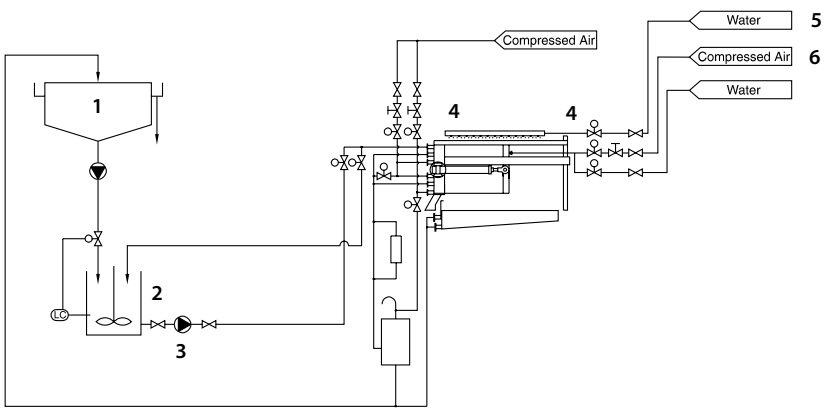
**Rinse water system** for the filter cloths. (5)

**Weighing system** for optimization of the operational parameters of filtration, compressed air drying, etc.

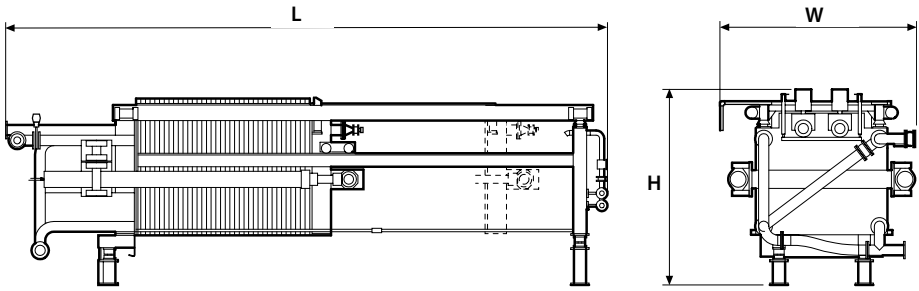
**Compressor** for compressed air supply. (6)

**Computer based control system** for operation and control of the filtration process.





## *Pressure filter – VPA 10*

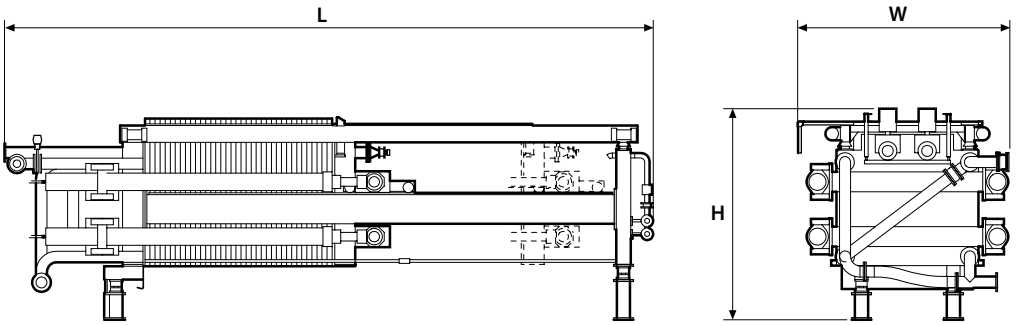



| Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight (empty) ton | Power** (hydraulic motor) high kW/hp | low kW/hp |
|---|---|---|---|---|---|---|
| VPA 10..-12* | 2 310 (91) | 5 500 (217) | 2 750 (108) | 7.2 | 22/30 | 11/15 |
| VPA 10..-16 | 2 310 (91) | 6 100 (240) | 2 750 (108) | 8.1 | 22/30 | 11/15 |
| VPA 10..-20 | 2 310 (91) | 6 700 (264) | 2 750 (108) | 9.0 | 22/30 | 11/15 |
| VPA 10..-24 | 2 310 (91) | 7 300 (287) | 2 750 (108) | 10.0 | 22/30 | 11/15 |
| VPA 10..-28 | 2 310 (91) | 7 900 (311) | 2 750 (108) | 11.8 | 22/30 | 11/15 |
| VPA 10..-32 | 2 310 (91) | 8 500 (335) | 2 750 (108) | 12.9 | 22/30 | 11/15 |
| VPA 10..-36 | 2 310 (91) | 9 100 (358) | 2 750 (108) | 14.0 | 22/30 | 11/15 |
| VPA 10..-40 | 2 310 (91) | 9 700 (382) | 2 750 (108) | 15.1 | 22/30 | 11/15 |

* 1012, 10 = filter chamber size10x 10 dm (40x40 inch),12 = number of chambers

** High kW/hp = low pressure stage, Low kW/hp = high pressure stage

## *Pressure filter – VPA 15*

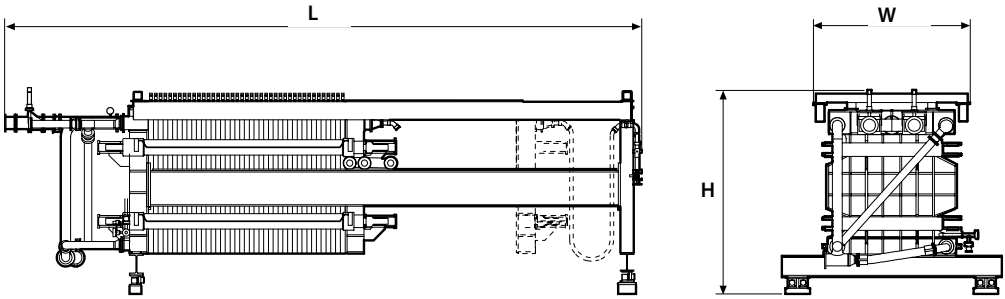



| Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight (empty) ton | Power** (hydraulic motor) high kW/hp | low kW/hp |
|---|---|---|---|---|---|---|
| VPA 15..-16* | 3 160 (125) | 7 600 (299) | 3 800 (150) | 24.7 | 45/60 | 22/30 |
| VPA 15..-20 | 3 160 (125) | 7 900 (311) | 3 800 (150) | 26.1 | 45/60 | 22/30 |
| VPA 15..-24 | 3 160 (125) | 8 500 (335) | 3 800 (150) | 27.5 | 45/60 | 22/30 |
| VPA 15..-28 | 3 160 (125) | 9 100 (358) | 3 800 (150) | 28.9 | 45/60 | 22/30 |
| VPA 15..-32 | 3 160 (125) | 9 700 (382) | 3 800 (150) | 31.2 | 45/60 | 22/30 |
| VPA 15..-36 | 3 160 (125) | 10 300 (406) | 3 800 (150) | 32.0 | 45/60 | 22/30 |
| VPA 15..-40 | 3 160 (125) | 10 900 (429) | 3 800 (150) | 33.2 | 45/60 | 22/30 |
| VPA 15..-46 | 3 160 (125) | 11 800 (465) | 3 800 (150) | 34.3 | 45/60 | 22/30 |
| VPA 15..-50 | 3 160 (125) | 12 400 (488) | 3 800 (150) | 37.5 | 45/60 | 22/30 |
| VPA 15..-54 | 3 160 (125) | 13 100 (516) | 3 800 (150) | 39.2 | 45/60 | 22/30 |

* 1516, 15 = filter chamber size 15x 15 dm (60x60 inch),16 = number of chambers

** High kW/hp = low pressure stage, Low kW/hp = high pressure stage

## *Pressure filter – VPA 20*




| Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight (empty) ton | Power** (hydraulic motor) high kW/hp | low kW/hp |
|---|---|---|---|---|---|---|
| VPA 20..-20* | 4 580 (180) | 10 203 (402) | 4 250 (167) | 56.0 | 75/100 | 30/40 |
| VPA 20..-24 | 4 580 (180) | 11 000 (433) | 4 250 (167) | 59.2 | 75/100 | 30/40 |
| VPA 20..-28 | 4 580 (180) | 11 800 (465) | 4 250 (167) | 62.4 | 75/100 | 30/40 |
| VPA 20..-32 | 4 580 (180) | 12 600 (496) | 4 250 (167) | 65.6 | 75/100 | 30/40 |
| VPA 20..-36 | 4 580 (180) | 13 400 (528) | 4 250 (167) | 68.8 | 75/100 | 30/40 |
| VPA 20..-40 | 4 580 (180) | 14 200 (559) | 4 250 (167) | 72.0 | 75/100 | 30/40 |
| VPA 20..-46 | 4 580 (180) | 14 800 (583) | 4 250 (167) | 76.8 | 75/100 | 30/40 |
| VPA 20..-50 | 4 580 (180) | 15 600 (615) | 4 250 (167) | 80.0 | 75/100 | 30/40 |

* 2020, 20 = filter chamber size 20x 20 dm (80x80 inch), 20 = number of chambers

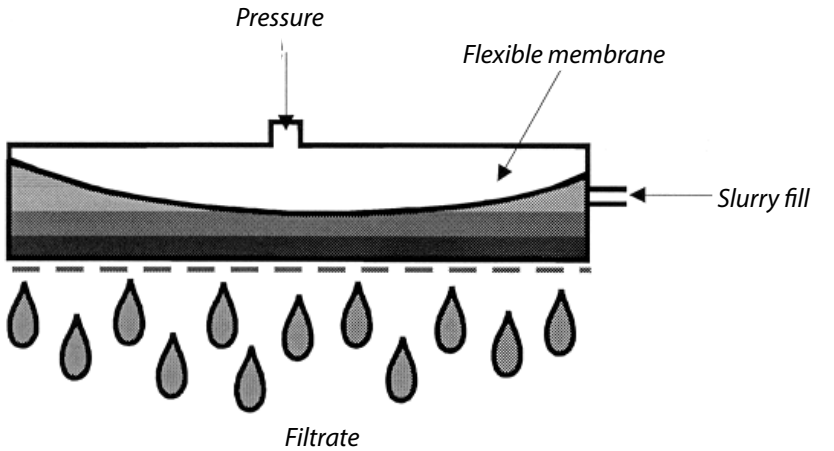
** High kW/hp = low pressure stage, Low kW/hp = high pressure stage

## *Tube press – Introduction*

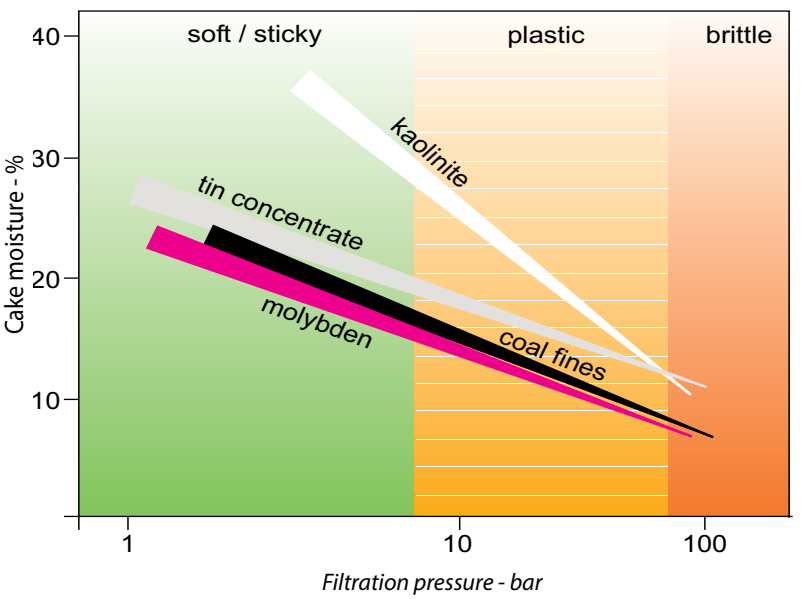
As particles continue to gets even finer,"low pressure dewatering" is not longer enough to overcome the strong capillary forces in the particle binding to liquid. To overcome this powerful binding with mechanical dewatering, the pressure has to be increased.

The tube press is special designed to operate at high pressure in applications were the process requires pressure up to 100 bar.

The tube press is a variable volume filter using flexible membrane to apply high pressure mechanical compression to the slurry that is dewateried.



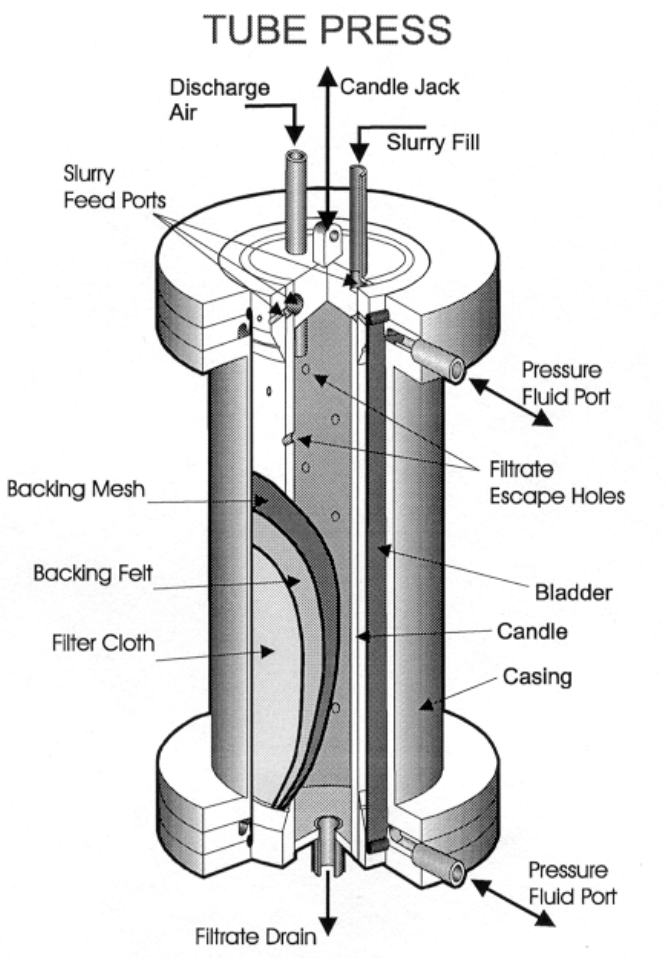

By applying a higher pressure or "driving" force to the filtration process a drier filter cake with better handling characteristics can be produced.




The tube press operates at pressures of up to 100 bar (1 450 psi) and was originally developed for dewatering of fine Kaolin slurries. It has since been applied to a variety of difficult filtration operations.

## *Tube press – Design*

- The outer casing has a flexible membrane (bladder) fastened at each end
- The inner candle has a filter media around its outer surface
- The candle has a series of filtrate drain holes around its circumference
- The feed slurry enters the tube press through the feed ports
- Fluid is pumped into and out of the unit through the pressure ports to create the filtration pressure
- The filtrate drains away through the drain pipe

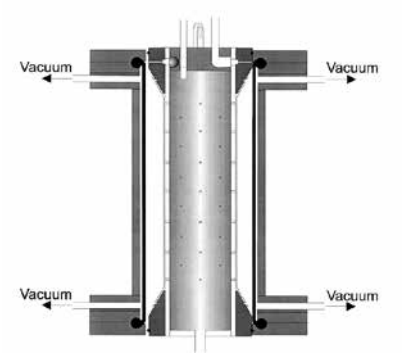


# *Tube press – Operation*

## *The filtration cycle*

### Step 1 – Starting cycle

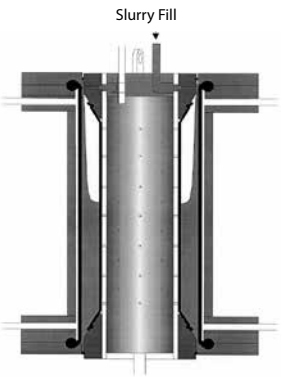
The tube press will start each cycle empty.




- The candle is in the closed position
- Hydraulic vacuum is applied
- The Bladder is pulled back against the casing

### Step 2 – Slurry fill

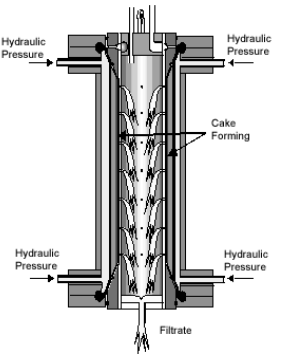
The tube press is then filled with the feed slurry.




The slurry enters the tube press through the porting in the top of the candle and fills the annular space between the filter and the bladder.

### Step 3 – Pressure phase

The filtration is applied by pumping a fluid, usually water, into the tube press through the pressure ports.

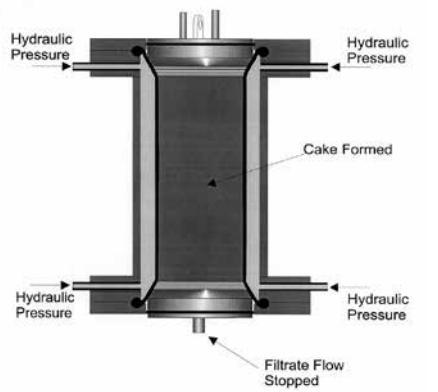



- The pressure water pushes the Bladder squeezing the slurry against the filter cloth
- The filtrate passes through the fliter cloth and runs to drain
- The solids are held by the filter cloth forming a cake

In order to take advantage of the faster filtering which occurs in the early stages and to take any slack in the system, the pressure is initially applied at low pressure/ high volume. At the appropriate point high pressure water is applied.

### Step 4 – Filtration complete

Eventually the stage is reached where no further filtration will take place.

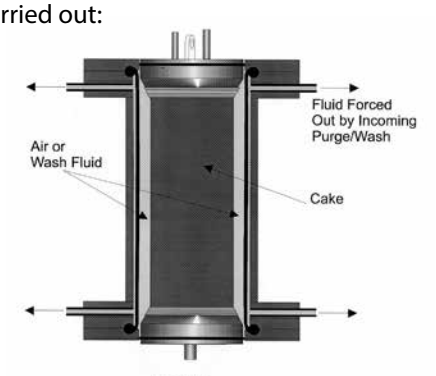



- Cake will be formed
- Filtrate will no longer flow

The next step in the process will depend on whether the cycle will include the air purging or washing of the cake. If air purge or cake wash is required then the next stage will be step 4. If not the next stage will be step 6.

**Step 5 – Air purge / Cake wash**

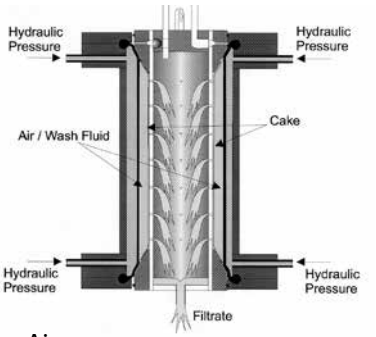
If it is necessary to treat the cake by air purging or washing, the following is carried out:




- The pressure fluid is forced out of the tube press by the incoming air or wash fluid
- The pressure fluid is restricted by a flow restrictor in order that the internal pressure in the Tube is maintained. This is necessary to ensure that the cake does not fracture

**Step 6 – Repeat high pressure**

Once the tube press unit has been filled with air or wash fluid the hydraulic high pressure is reapplied.

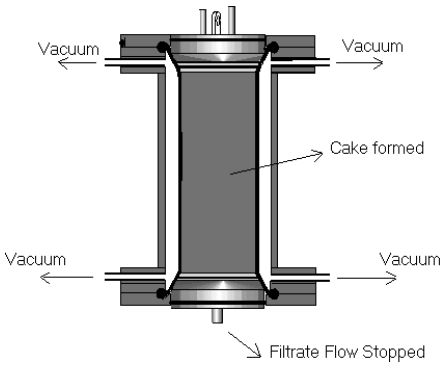



- Air purge:
  - The air will force further filtrate from the cake resulting in a drier cake
  - The wash fluid may also be used to remove soluble materials from the cake

It is possible to carry out multiple air purges or cake washers

**Step 7 – Vacuum**

When the final high pressure stage is completed it is necessary to enter the discharge sequense.

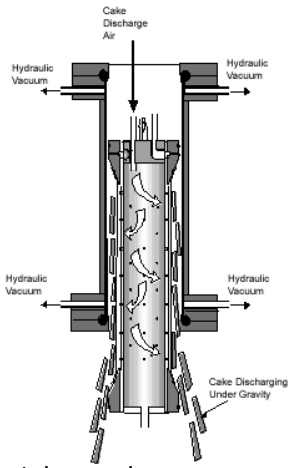



- The hydraulic vacuum draws the pressure fluid out of the tube press, pulling the Bladder away from the cake
- The bladder is pulled tight against the casing wall

To ensure the bladder is fully against the Casing wall and away from the candle the system is equipped with a vacuum detector which will give a "proceed" signal when the appropriate level of vacuum is reached.

**Step 8 – Discharge**

When the vacuum level has been achieved the discharge will proceed.




- Candle is lowered
- Air is blown into the candle expanding the filter cloth which in turn fractures the cake which drops under gravity

- The candle then returns to the closed position
- For cakes which are reluctant to discharge, the system allows for multiple candle movements
- The candle returns to the closed position to commence the next cycle
- The system will check that the tube is empty and if so the nect cycle will commence
- Should the system detect that more than a set amount of cake is retained then the tube press will be parked and the alarm sound

## *Tube press – Examples of applications*



**MINERALS**

- Kaolin
- Calcium Carbonate (including ground calcium carbonates)
- Clays (other than Bentonitic types)
- Seawater Magnesia
- Steel making Sludges (BOF sludge)
- Titanium Dioxide
- Iron Oxide
- Molybdenium
- Copper Concentrate
- Zink oxide
- Lime
- Gypsum
- Tin Concentrate
- Underground water at precious metal mines

**CHEMICALS**

- Tri-Calcium Phosphate
- Di-Calcium Phospate
- Copper Pyro-Phosphate
- Calcium Hypochlorite

**EFFLUENTS**

- Titanium Dioxide wastes
- Fluoritic muds
- Spent bed slurry

**OTHERS**

- Pharmaceuticals
- Sugar refining carbonates
- Pigments
- Yeasts
- Waxes (in oil production)

**The following materials are not suited for dewatering in a tube press**

- Fibrous materials (sewage, water treatment sludges, pulp & paper, fruit)
- Oily materials (oil contaminated muds, scrap effluents)
- Very dilute slurries
- Bentonite type clays
- Rubber wastes and latex materials
- Hot processes (>55-60°C, 130-140°F)

## *Tube press – Material of construction*

**Wetted parts** – All metallic components of the tube press which come into contact with the process slurry is made from duplex stainless steel.

**Casing** – The casing and non-wetted parts are generally made from carbon steel.

**Bladder** – Standard material is natural rubber. Other elastomers can be considered for special process applications.

**Filter cloth** – Selected against specific process requirements.

## *Tube press – Sizes*

The tube press 500 series is available mainly in two different sizes.

**500 series**. Casing diameter 500 mm. Nominal lengths available 1 500 mm and 3000 mm. Maximum pressure 100 bar (1 450 psi).

| Model | 500 Series 1.5 m | 500 Series 3 m |
|---|---|---|
| Filtration pressure - max. (bar) | 100 | 100 |
| Length of candle (mm) | 1 500 | 3 000 |
| Candle diameter (mm) | 389 | 389 |
| Filter area ($m^2$) | 1.75 | 3.47 |
| Effective volume (liters) | 100 | 200 |
| Candle weight (kg) | 580 | 1 100 |
| Total weight (kg) | 2 000 | 3 000 |
| Crane height (m) | 6.17 | 9.17 |

See also data sheet 6:61

## *Tube press – Sizing*

The throughput for a tube press depends on:

- Cycle time
- Weight of each cake drop (chamber capacity)

**Typical cycle time without air-purge**

| | |
|---|---|
| Low pressure hydraulics | 0 – 5 sec. |
| Slurry fill | 10 – 30 sec. |
| Low pressure hydraulics | 10 – 30 sec. |
| High pressure hydraulics (100 bar) | 60 – 360 sec. |
| (could be less than 60 sec. to more than 10 min.) | |
| Vacuum and discharge | 45 – 90 sec. |
| ***Total cycle time*** | ***125 – 515 sec.*** |

**Cycle time with one air-purge**

| | |
|---|---|
| Low pressure hydraulics | 0 – 5 sec. |
| Slurry fill | 10 – 30 sec. |
| Low pressure hydraulics | 10 – 30 sec. |
| High pressure hydraulics (100 bar) | 30 – 180 sec. |
| *Air - purge I:* | |
| Air injection | 30 – 60 sec. |
| High pressure hydraulics (25 bar) | 60 – 360 sec. |
| Vacuum and discharge | 45 – 90 sec. |
| ***Total cycle time*** | ***185 – 755 sec.*** |

Second and third air-purge could be applied but are very seldom used.

Most effect is obtained with the first air purge, and the throughput for the press is reduced considerably with each air-purge applied.

**A cycle incorporating cake wash would be similar to air-cycle above.**

## *Tube press – Cycle times and cake moisture*

| **Typical cycle times and rest cake moisture:** | **time (sec)** | **moisture (%)** |
|---|---|---|
| Fine coal. without air purge | 220 | 23.0 |
| Fine coal. with air purge | 280 | 15.0 |
| Zinc concentrate. without air purge | 174 | 9.4 |
| Zinc concentrate. with air purge | 200 | 6.2 |
| Zinc concentrate with air purge | 273 | 13.2 |
| Lead concentrate without air purge | 297 | 12.1 |



## *Tube press – Capacity*

The amount of solids filled into the tube each cycle depends on optimal cake thickness, solids specific gravity, feed slurry density (cake build up) etc.

The capacity per unit (500 series) for some typical applications are given in following table:

| **Product** | **Slurry feed (% solids w/w)** | **Cake moisture (%)** | **Output/Tube 3m (kg/h dry)** | **(lb/h dry)** |
|---|---|---|---|---|
| Tin concentrate | 45 | 9.0 | 1 250 | 2 750 |
| Coal fines | 45 | 15.5 | 1 200 | 2 650 |
| Copper fume | 35 | 20.0 | 450 | 990 |
| Copper supergene | 60 | 11.5 | 1 300 | 2 900 |
| Lead concentrate | 60 | 7.0 | 2 250 | 5 000 |
| Zinc concentrate | 60 | 7.5 | 2 250 | 5 000 |
| China clay filler | 25 | 16.5 | 350 | 770 |
| Iron oxide | 55 | 20.0 | 1 500 | 3 300 |
| Acid effluent | 15 | 35.0 | 375 | 825 |
| Sulphur effluent | 20 | 35.0 | 415 | 910 |
| Mixed sulphides | 40 | 14.0 | 2 250 | 5 000 |

**Ex: Dewatering of 9.5 t/h (dry) tin concentrate (well thickened) in tube press.**

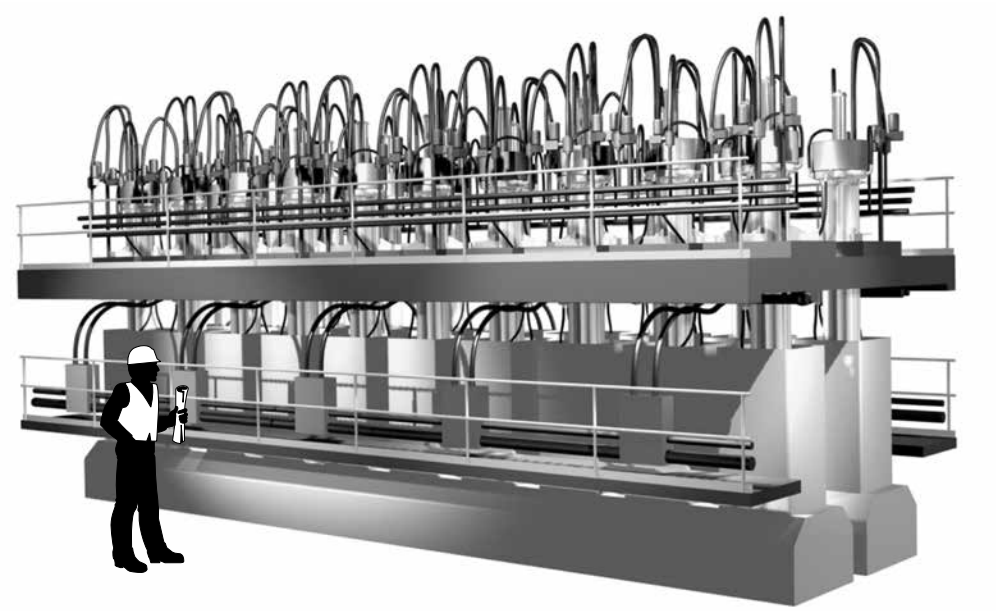
*Capacity per tube = 1250 kg/h (dry)*

*9500/1250 = 7,6*

*Select 8 tube presses type 500 !*

## *Tube press – Product systems*

### *Pump drive*





A tube press plant will contain the appropriate number of tube units according to the overall capacity required.

The units are usually supplied and installed in modules. Each module consists of a support raft to take two tube units, complete with all local valving and service header pipework. The rafts are designed to be coupled to allow the tube units to be configured in single or double lines.

The support steelwork, ladders, walkways, etc., will be purpose designed to suit the installation.

The service ancillaries to operate the plant are usually supplied as independent skid mounted units and consist of the following

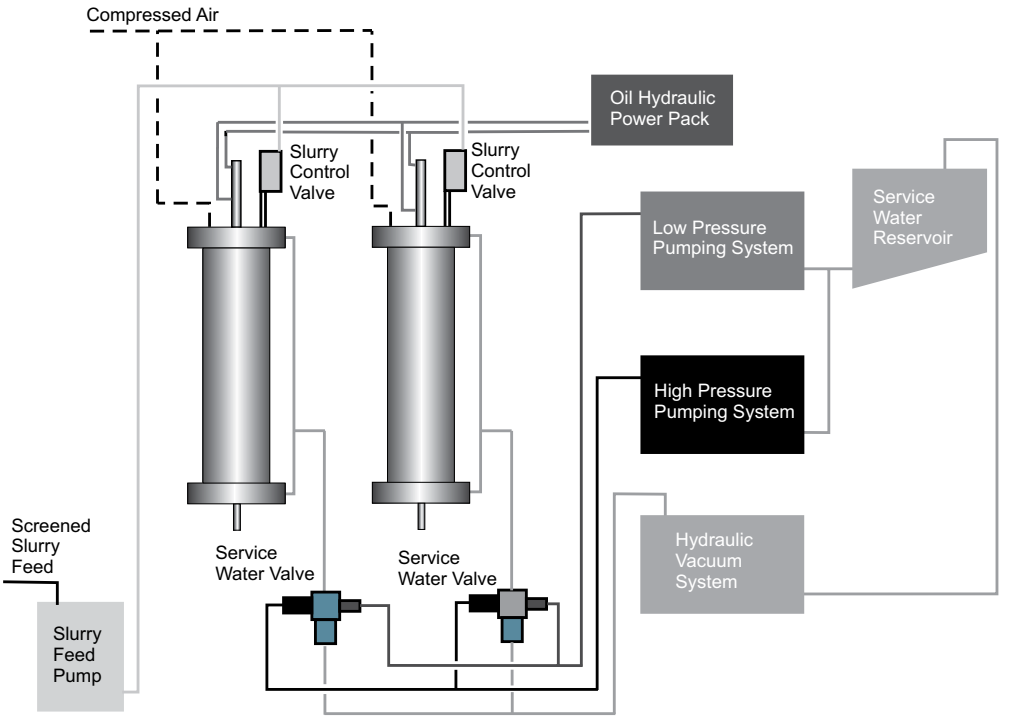
- Slurry pump set
- Low pressure filtration pump set
- High pressure filtration pump set
- Vacuum vessel and pump set
- Filtration fluid storage tank
- Oil hydraulic power pack (for candle movement at discharge)

The pipework and cabling to connect these items to the raft modules will be purpose designed to suit the installation.

The plant is controlled by a PLC based system which will normally incorporate full graphics and data storage/handling for optimum plant management.

## Upgrading

For the tube press to operate it requires an infrastructure of ancillary equipment to provide the necessary services. A general pump drive product system is shown below.




**These services are:**

- Slurry feed
- Filtration pressure system
- Low pressure
- High pressure
- Vacuum
- Candle jack hydraulics
- Oil hydraulic power pack
- Compressed air
- PLV based control system

## *Tube press booster system*

The tube press booster is a compact intelligent dewatering system for small scale applications in mineral, chemical and pharmaceutical industries.

**"Compact filtration unit" / Booster system**

The booster is an individual drive system closely coupled with the tube press.

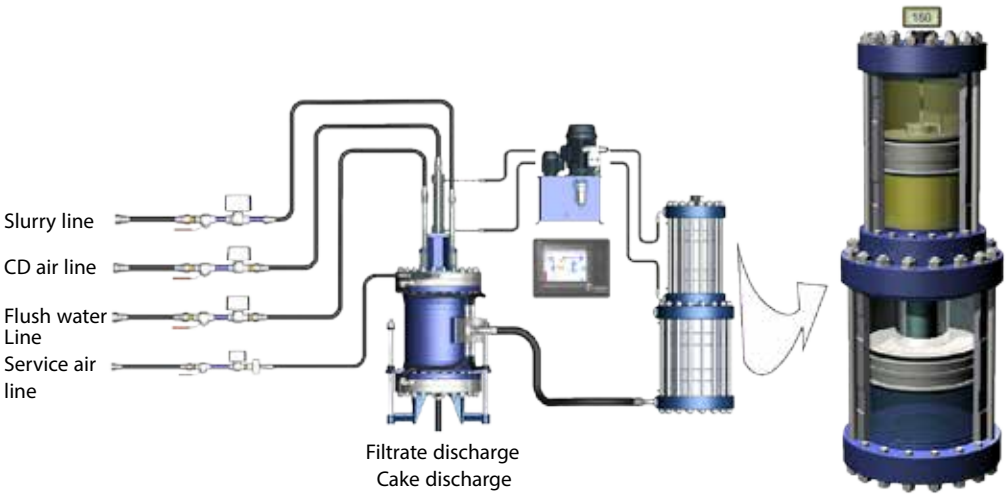
The installation is compact and combining one motor to generate the mechanical dewatering press force.

The system incorporates fully optimized control of the complete process, including feed back and statistical analysis of each press cycle.

## *Mechanical description*

The drive unit incorporates an oil hydraulic power pack and a booster. The oil driven hydraulic power pack provides the driving force, which is converted via the booster unit into a water based pressure medium.

The pressure and dewatering speed is controlled via the control system, which is constantly receiving feedback from sensors and a positional pump. This results in the ability to continuously increase the pressures matching the dewatering curve of the material.




## *Control system*

The tube press is operated from the operator's monitor located on the control panel.

The monitor is connected to a PLC that handles the control logics and interlockings.

All process specific data and parameters can be set and adjusted from the monitor in the settings menu.

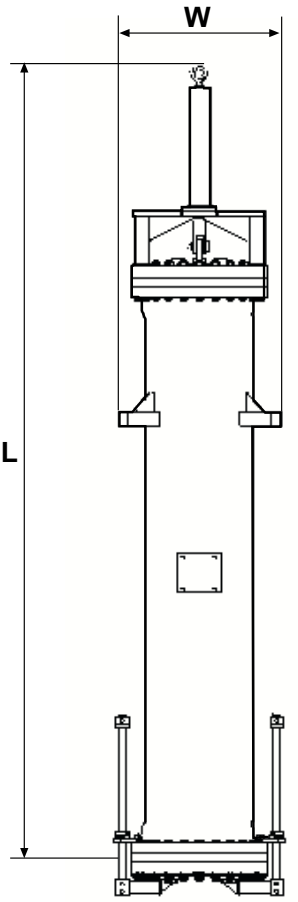
Cycle time, press weight, etc., are presented on the monitor.

## *The booster system*

Small to medium installation size installation advantages:

- Low cake moisture
- Excellent liquid/solid separation
- Compact design and is easy to install.
- Fully optimized control
- Useful quality production information and data exchange
- Easy to expand
- Few moving parts
- Increased efficiency by on line process control
- Environmental advantage by high grade of recovery
- Maximum energy exchange
- Closed media circuit
- Low installed power
- Maintenance friendly
- Fully automated

## *Tube press*




| Model | L mm (inch) tube length | W mm (inch) | Weight (empty) ton | Filter area $m^2$ ($ft^2$) | Max operating .pressure bar (psi) |
|---|---|---|---|---|---|
| SC 500-1,2* | 3 500 (138) | 860 (34) | 1.8 | 1.35 (14.5) | 100 (1 450) |
| SC 500-1,5 | 3 800 (150) | 860 (34) | 2.0 | 1.73 (18.6) | 100 (1 450) |
| SC-500-3,0 | 5 200 (205) | 860 (34) | 3.0 | 3,45 (37.1) | 100 (1 450) |

## *Tube press booster*

| Model | Tube chamber volume $cm^3$ ($inch^3$) | Filter area $m^2$ ($ft^{2)}$) | Max. pressure bar (psi) | Installed power kW (hp) |
|---|---|---|---|---|
| SC 500-1,2* | 75 (4.6) | 1,35 (14.5) | 100 (1 450) | 7,5 (10) |
| SC 500-1,5 | 100 (6.1) | 1,73 (18.6) | 100 (1 450) | 7,5 (10) |
| SC-500-3,0 | 200 (12.2) | 3,45 (37.1) | 100 (1 450) | 11 (15) |

* Lab unit for special applications.

## *Thermal processing – Introduction*

The level of dewatering that can be achieved through mechanical processes such as VPA's and tube presses is limited. If further upgrading is required, it must be achieved through thermal processing. Thermal processing is normally classified according to operating temperature.

### *Thermal low (100 - 200° C)*

Used for drying – evaporating of liquids from solids - drying
Type of equipment

- Direct heat rotary dryers
- Indirect heat rotary dryers
- Steam tube dryers
- Indirect heat screw dryers (Holo-Flite®)
- Fluid bed dryers

### *Thermal medium (850 - 950°C)*

Used for various calcining, clay swelling, limestone burning and foundry sand burn out
Type of equipment

- Direct heat rotary kilns
- Indirect heat rotary kilns
- Vertical kilns
- Fluid bed calciners

### *Thermal high (1300 -1400°C)*

Used for vaious calcining operations
Type of equipment

- Direct heat rotary kiln
- Travelling grate and straight grate induration furnaces

### *Thermal processing – basics*

Thermal processing equipment is typically supplied as an integrated system consisting of:

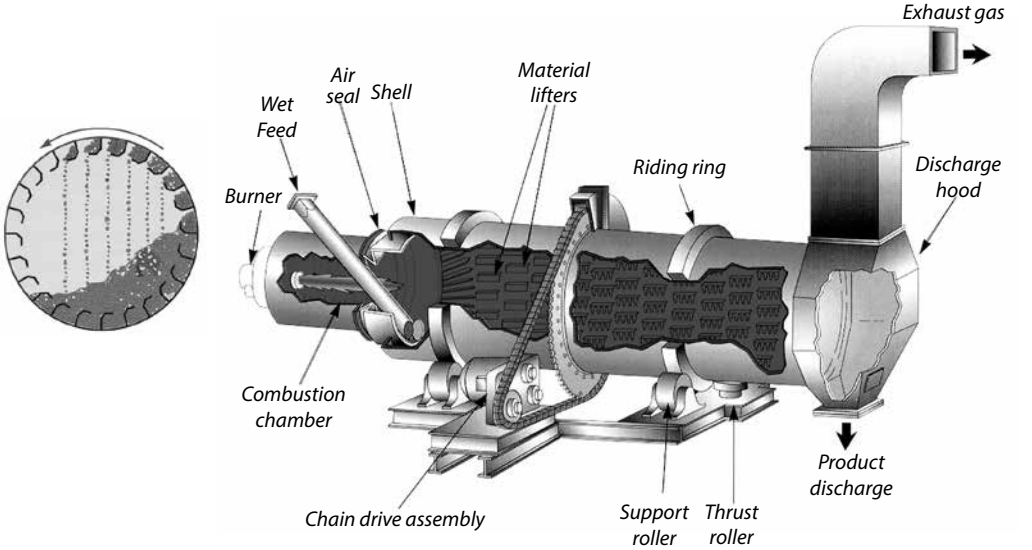
- Mechanical dryer or kiln, see above
- Feed and product handling equipment
- Combustion system (burner, fans, fuel system, etc.)
- Offgas handling equipment
- Dust collection system (wet or dry)
- Cooling system (optional)

For thermal processing systems, fuel consumption is one of the largest and most important Operational Expenses. It's therefore critical that systems are designed in a manner that optimizes the fuel efficiency and the overall heat balance.

As processing temperatures increase from the thermal low range to the thermal high range, there are more opportunities to conserve energy and recover heat. For instance, low temperature dryers are usually not insulated as they typically have insignificant energy losses to atmosphere. However, high temperature kilns are always refractory lined, not only to protect the mechanical parts from the high temperatures but also to reduce the energy losses through radiation to atmosphere. Additionally, the high temperatures in the product and off-gases of a kiln provide greater opportunity for heat recovery systems.

## *Direct heat rotary dryer (Cascade type)*

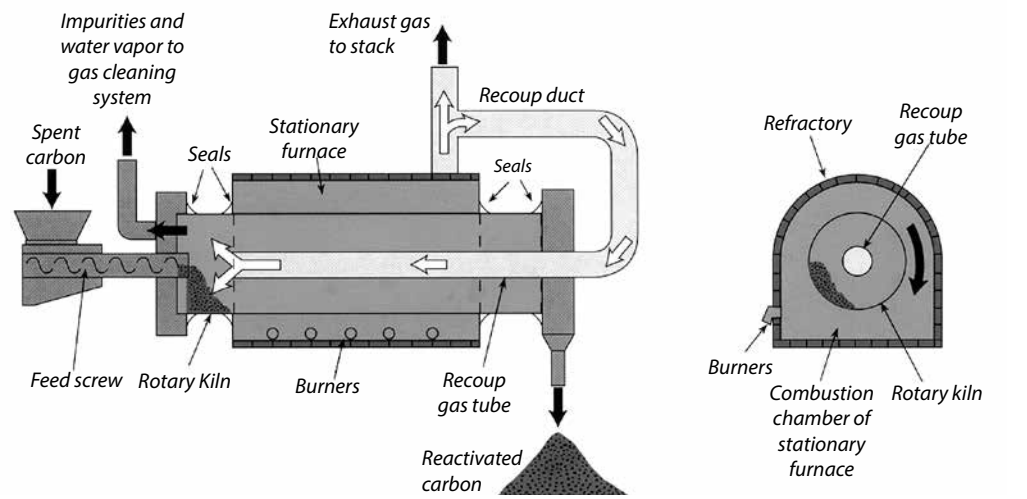
- Work horse of the mineral industry
- Wide range of internal designs for effective drying from start to end
- Special seals for closely controlled atmosphere
- Effective combustion and low maintenance burners, safe and reliable
- Diameter <0,5-7 m (2 –23 ft), length 6 – 55 m (70 – 180 ft). Feed rates from less than 1 ton to 1000 tons per hour
- Applications in minerals, clay, sand, aggregates, heavy chemicals and fertilizers






## *Indirect heat rotary dryer (Kiln)*

- Controlled environment interior excludes products of combustion
- Heat transfer by conduction and radiation
- Pulse-fired burners available
- Facilitates recovery of off-gases and product vapours
- Diameter 0,5m – 5,5 m (1.5-18 ft). Length 2.5 m to 28 m (8 – 90 ft).
- Applications in hazardous-, ultra fine- and combustible materials.
- Regeneration of active carbon, pyrolysis of waste rubber (car types), and plastics.

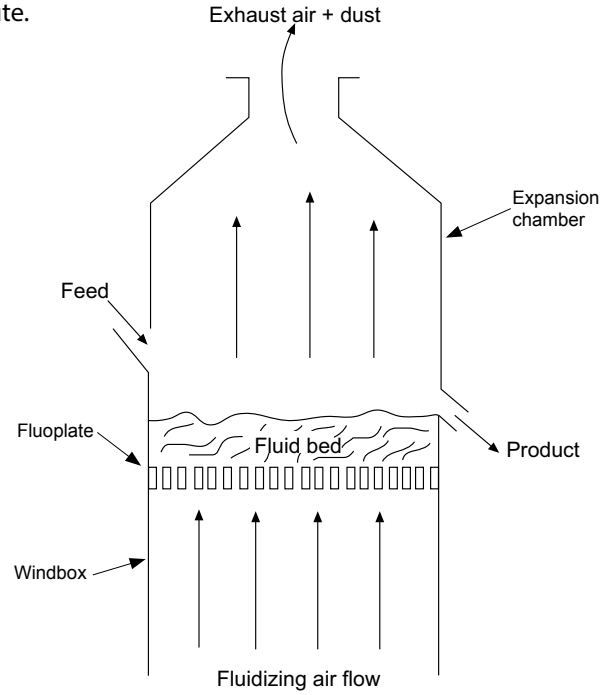


# *Fluidized bed*

**Principals**

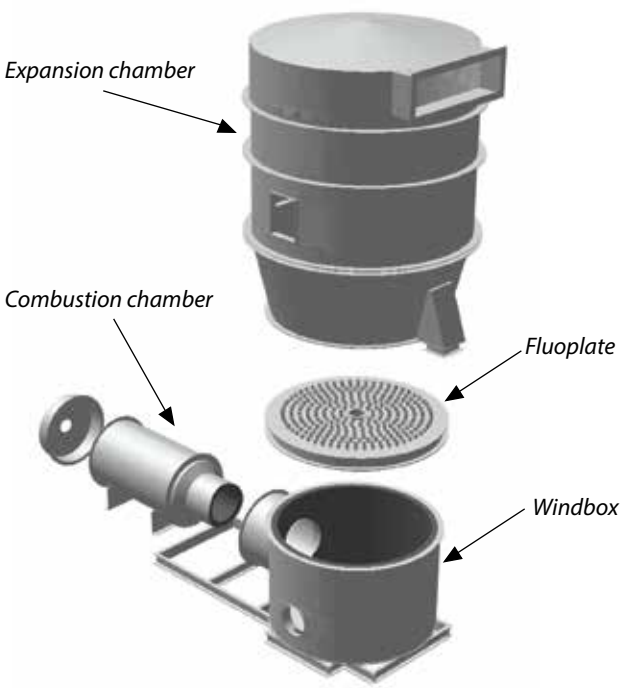
In a fluid bed, gases are forced from the windbox through a distributor plate, called the Fluoplate, which delivers the flow evenly to the particle bed and expansion chamber. As the flowrate of the gases is increased to achieve the fluidization velocity, the bed of particles expands and begins to behave very similarly to a fluid with all particles in motion.

Product is discharged from the fluid bed as it overflows a weir and spills down the product chute.




## *Fluidized bed – key components*

- Combustion chamber
- Windbox
- Fluoplate
- Expansion chamber



## *Fluid bed – advantages*

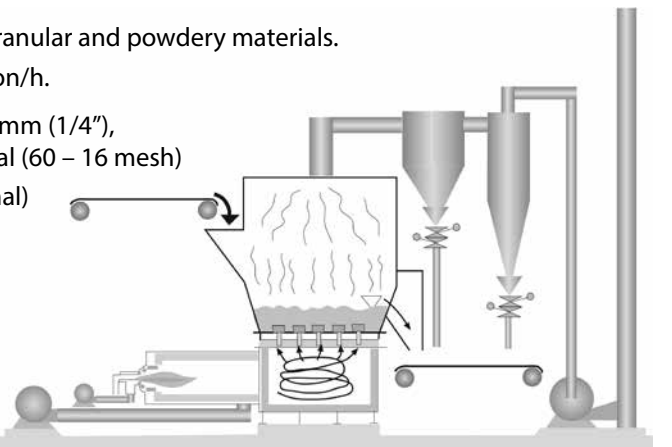
- A fluid bed behaves like a fluid allowing the use of equipment with no moving parts.
- The air/particle contact creates optimal heat and mass transfer
- Good agitation and mixing promotes consistent product quality

## *Fluid bed – applications*

- Drying with bed temperature 100°C (212°F), (main application area)
- Cooling with bed cooled by water pipes
- Calcining with bed temperatures of 750 – 1200°C (1 382°F – 2 192°F)
- Combustion at operating temperatures of 750 – 900°C (1 382°F – 1652°F), (solid fuels combusted within a sand bed)

## *Fluid bed dryer*

- For drying of most granular and powdery materials.
- Capacity up to 300 ton/h.
- Particle size minus 6 mm (1/4"), 0.25 – 1.0 mm optimal (60 – 16 mesh)
- Size range 6:1 (optimal)

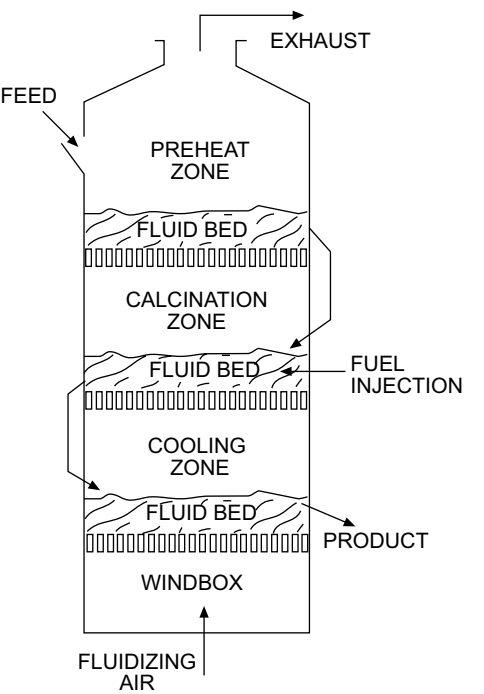


## *Fluid bed calciner*

### *Operating temperatures 750 –1200°C.*

At such temperatures fuel (gaseous, liquid or solid) is injected directly into the fluid bed.

Heat recovery is done by multistaging the product zones vertically. Calcination gases preheat the feed whilst a cooling zone cools the product and preheats the fluidizing air.



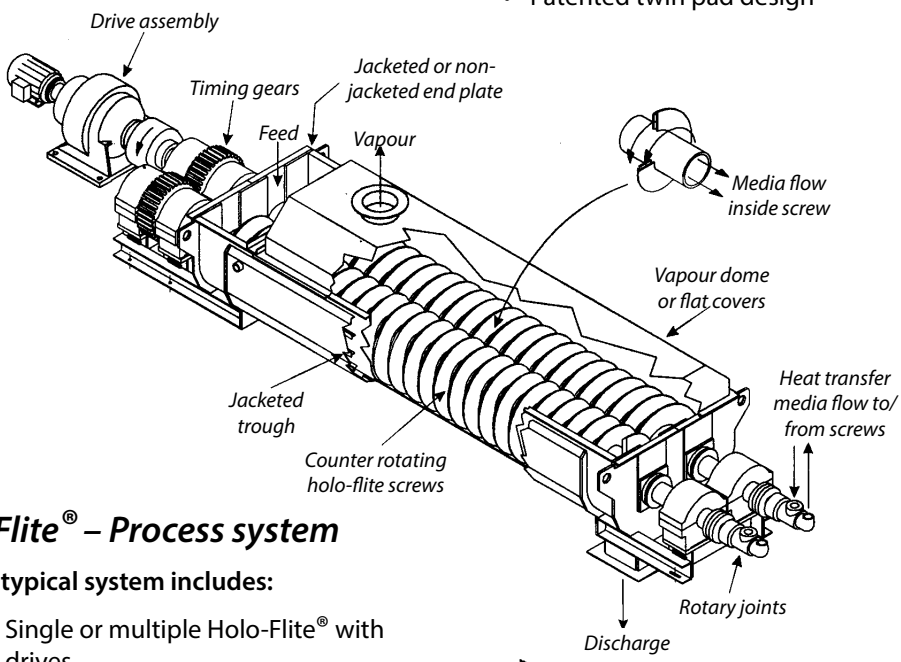
# *Indirect heat screw dryer (Holo-Flite®)*

## *Operating principle*

The principle for the Holo-Flite® dryer is the same as for the indirect heat rotary dryer (described earlier) with the difference that the product to be dried is continuously conveyed by means of the rotating screw flights. By controlling the temperature of the heat transfer medium and the screw speed the drying process can be closely controlled. Heat transfer medium is normally recirculated giving a high thermal efficiency. The design is very compact giving certain advantages in application layouts.

## *Holo-Flite®– design*

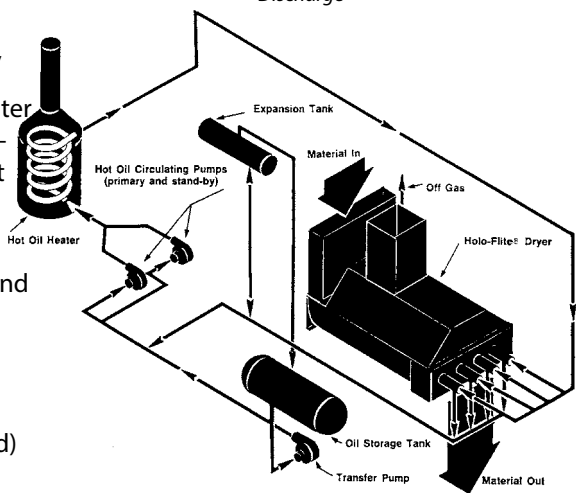
- Design can take up temperature variations 0 – 1200° C (30 – 2000° F)
- Construction material carbon steel, and various alloys as required by application for resistance to corrosion and abrasion.
- Screw diameter 178 – 915 mm (7 – 36”), 1,2 or 4 screws
- Concurrent or counter-current flow of heat transfer medium
- Patented twin pad design




# *Holo-Flite® – Process system*

**A typical system includes:**

- Single or multiple Holo-Flite® with drives
- Heat transfer medium supply
- Medium heating system (heater with control system, fuel storage and expansion tank, heat medium transfer pump, hot medium circulation pumps
- Safety protection (sprinkler and nitrogen)
- Optional PLC controls
- Vapour exhaust fan
- Dust collector (when required)



### *Holo-Flite®– Heat transfer medium*

| | | |
|---|---|---|
| Steam (up to 10 bar) | 100 – 200°C | 200 – 400°F |
| Hot Oil | 150 – 350°C | 300 – 660°F |

### *Holo-Flite®– applications*

Any material that can be successfully transported through a screw conveyor can also be thermally processed in a Holo-Flite®. The only restriction is with sticky materials that adhere and build up on the surface of the transporting flights. The maximum recommended particle size is 12mm (1/2").

The Holo-Flite® is an excellent fit for thermally processing materials such as:

- Coal fines
- Mineral concentrates (gold, silver, molybdenum, rare earths)
- Mineral fines
- Carbon black
- Iron powder
- Other valuable granular and powdery material



### *Holo-Flite® – sizing*

Holo-Flite® sizing is a complicated computer exercise that is normally based on laboratory or pilot test work

Some typical drying application figures:

| | | | |
|---|---|---|---|
| **Limestone fines** | **12 t/h** | **15°C in** | **138°C out** |
| Equipment used: one 4-screw machine, flight dia 600 mm (24"). Length 7.2m (24ft) | | | |
| **Potassium chloride** | **9 t/h** | **0°C in** | **110°C out** |
| Equipment used: one 2-screw machine, flight dia 400 mm (16"). Length 6 m (20 ft) | | | |

See also data sheet 6:57.

## *Cooling technologies*

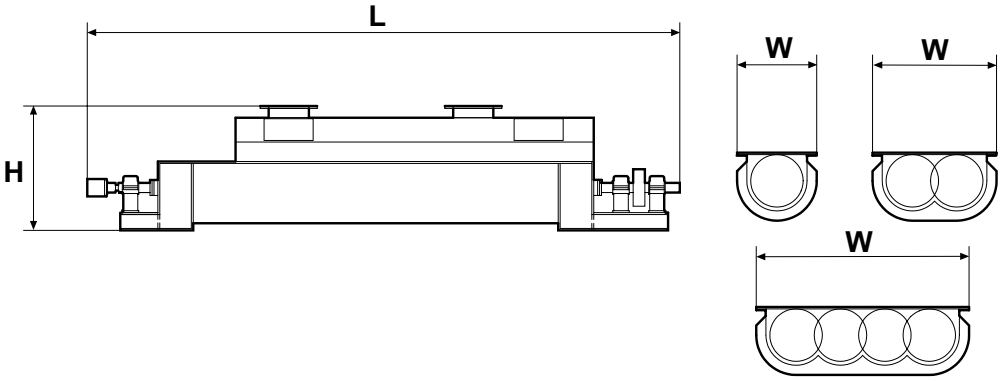
In most thermal medium and high processing applications the temperatures of discharged products are high. Coolers are used to lower the temperature for product handling equipment and also to recover heat.

### *Rotary drum coolers*

Normally there are three basic designs:

- **Air swept coolers** built similar as a counter flow direct heat rotary dryer, where hot gasses are replaced with ambient air
- **Water cooled shell coolers** where the drum shell is cooled with water or is submerged in a pool of water.
- **Water tube coolers** in which heat is transferred from the material to water circulated through tubes inside the cooler.

## *Indirect heat screw dryer – Holo-Flite®*




| Model | H - overall mm (inch) | L - overall mm (inch) | W - overall mm (inch) | Weight empty tonnes | Power (typical) kW/hp |
|---|---|---|---|---|---|
| S0710-4* | 335 (13) | 4191 (165) | 305 (12) | 0,8 | 0.37/0.5 |
| S0714-4 | 335 (13) | 5410 (213) | 305 (12) | 1,0 | 0.37/0.5 |
| D0710-4 | 335 (13) | 4191 (165) | 457 (18) | 1,2 | 0.56/0.75 |
| D0714-4 | 335 (13) | 5410 (213) | 457 (18) | 1,5 | 0.75/1 |
| S1210-5 | 565 (22) | 4496 (177) | 457 (18) | 1,3 | 1.2/1.5 |
| S1218-5 | 565 (22) | 6934 (273) | 457 (18) | 1,9 | 2.2/3 |
| D1210-5 | 565 (22) | 4826 (190) | 711 (28) | 2,3 | 2.2/3 |
| D1218-5 | 565 (22) | 7264 (286) | 711 (28) | 2,5 | 3.7/5 |
| S1614-6 | 635 (25) | 6096 (240) | 559 (22) | 2,2 | 2.2/3 |
| S1618-6 | 635 (25) | 7315 (288) | 559 (22) | 2,5 | 3.7/5 |
| D1614-6 | 635 (25) | 6096 (240) | 864 (34) | 3,5 | 5.5/7.5 |
| D1618-6 | 635 (25) | 7315 (288) | 864 (34) | 4,5 | 7.5/10 |
| S2414-6 | 881 (35) | 6299 (248) | 762 (30) | 3,5 | 3.7/5 |
| S2424-6 | 881 (35) | 9347 (368) | 762 (30) | 5,5 | 5.5/7.5 |
| D2414-6 | 881 (35) | 6706 (264) | 1219 (48) | 6,5 | 7.5/10 |
| D2424-6 | 881 (35) | 9754 (384) | 1219 (48) | 9,5 | 11/15 |
| Q2418-6 | 881 (35) | 7925 (312) | 2159 (85) | 15,0 | 15/20 |
| Q2424-6 | 881 (35) | 9754 (384) | 2159 (85) | 20,0 | 22/30 |
| S3022-7 | 1092 (43) | 8941 (352) | 965 (38) | 7,5 | 5.5/7.5 |
| S3028-7 | 1092 (43) | 10770 (424) | 965 (38) | 13,0 | 7.5/10 |
| D3022-7 | 1092 (43) | 9423 (371) | 1600 (63) | 16,5 | 11/15 |
| D3028-7 | 1092 (43) | 11252 (443) | 1600 (63) | 26,0 | 15/20 |
| Q3022-7 | 1092 (43) | 9423 (371) | 2870 (113) | 33,5 | 22/30 |
| Q3028-7 | 1092 (43) | 11252 (443) | 2870 (113) | 42,0 | 30/40 |
| S3622-8 | 1321 (52) | 9017 (355) | 1092 (43) | 17,0 | 7.5/10 |
| S3628-8 | 1321 (52) | 10846 (427) | 1092 (43) | 21,0 | 11/15 |
| D3622-8 | 1321 (52) | 9525 (375) | 1803 (71) | 25,5 | 15/20 |
| D3628-8 | 1321 (52) | 11354 (447) | 1803 (71) | 32,0 | 18.5/25 |
| Q3622-8 | 1321 (52) | 9525 (375) | 3226 (127) | 50,5 | 30/40 |
| Q3628-8 | 1321 (52) | 11354 (447) | 3226 (127) | 63,0 | 37/50 |

*S 710 - 4, S = single screw, 7 = screw diameter, inch, 10 = screw length 10ft, – 4 = screw pitch 4 inch

D = double screw, Q = Quadruple screw

## Fluid bed coolers

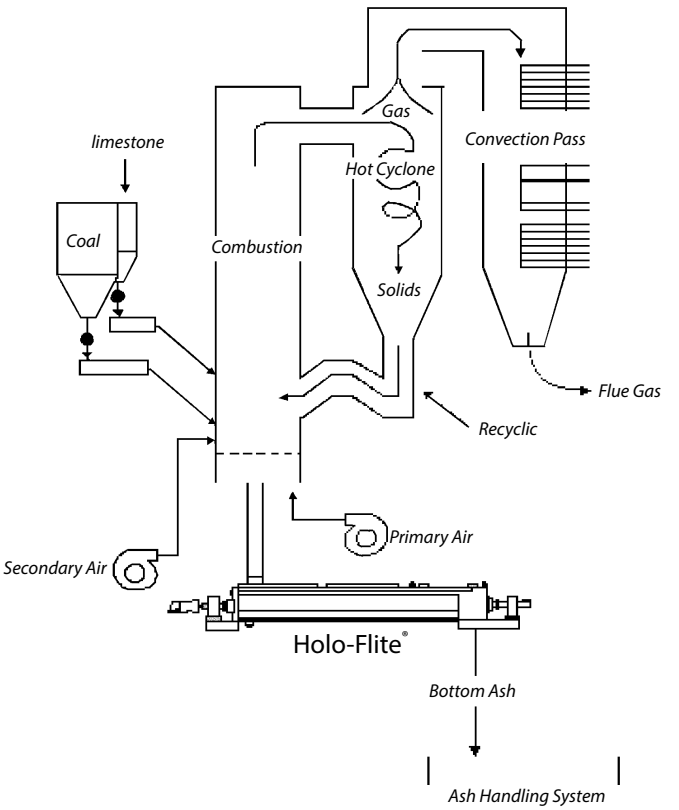
The principles of fluid bed can be used also for cooling purposes. In this case the fluid bed is cooled by the fluidizing air and internal water pipes.

## Holo-Flite® coolers

The Holo-Flite® is most often used for cooling applications. In these cases, the cooling medium circulating through the screw is water or a water/glycol mixture. Since the design of the screw permits very high feed temperatures, and due to its vertically compact profile, the Holo-Flite® is a perfect fit for boiler bottom ash cooling applications.

## Ash cooling

Circulating fluidized bed boiler




## Coolers and heat recovery

Rising fuel prices and heightened awareness of environmental issues drive an ever increasing demand for energy efficiency in thermal processing systems.

The most energy efficient systems usually incorporate heat recovery that makes valuable use of the energy released from product cooling.

# Iron ore pelletizing

## What is iron ore pelletizing? Purpose and use of iron ore pelletizing

Pelletizing is the process through which iron ore fines are transformed into an agglomerated form called "iron ore pellets" suitable for use in an iron-making furnace such as a blast furnace or electric arc furnace. Each iron making furnace has specific iron ore pellet chemistry requirements that govern the design criteria of an iron ore pelletizing plant. In its end product form, a typical iron ore pellet is roughly spherical in shape, measuring from six mm to sixteen mm in diameter and having a crushing strength of over 200 Kg, although some variations in these typical parameters can be specified and targeted in the design process.

Under the iron ore pelletizing process, finely ground iron ore is slightly moistened and mixed with a binder. This mixture is continuously fed to a balling disc or drum that forms spheres from the ore fines. The spheres, prior to firing, are called green pellets. Upon discharge from the balling apparatus, the green pellets are separated according to size. Those within the desired size range are transported and fed into an indurating process where they are hardened (indurated) by baking in an oxidizing atmosphere. Off-size pellets are recycled back through the process. The indurating is carried out in a high temperature furnace designed and optimized to achieve the required pellet chemistry. In the final form, the finished pellet product is commonly called "fired pellets" indicating that they have been indurated and hardened. After the pellets are indurated, the fired pellets are transported and screened as necessary to the size required by the customer.

The chemistry, physical properties and metallurgical properties of the fired pellets can be adjusted to suit the end use (iron making furnace) by combining the fine ore mixture with various additives prior to firing. The temperature profile of the indurating furnace can also be adjusted to influence the physical and metallurgical properties of the fired pellets over a wide range.

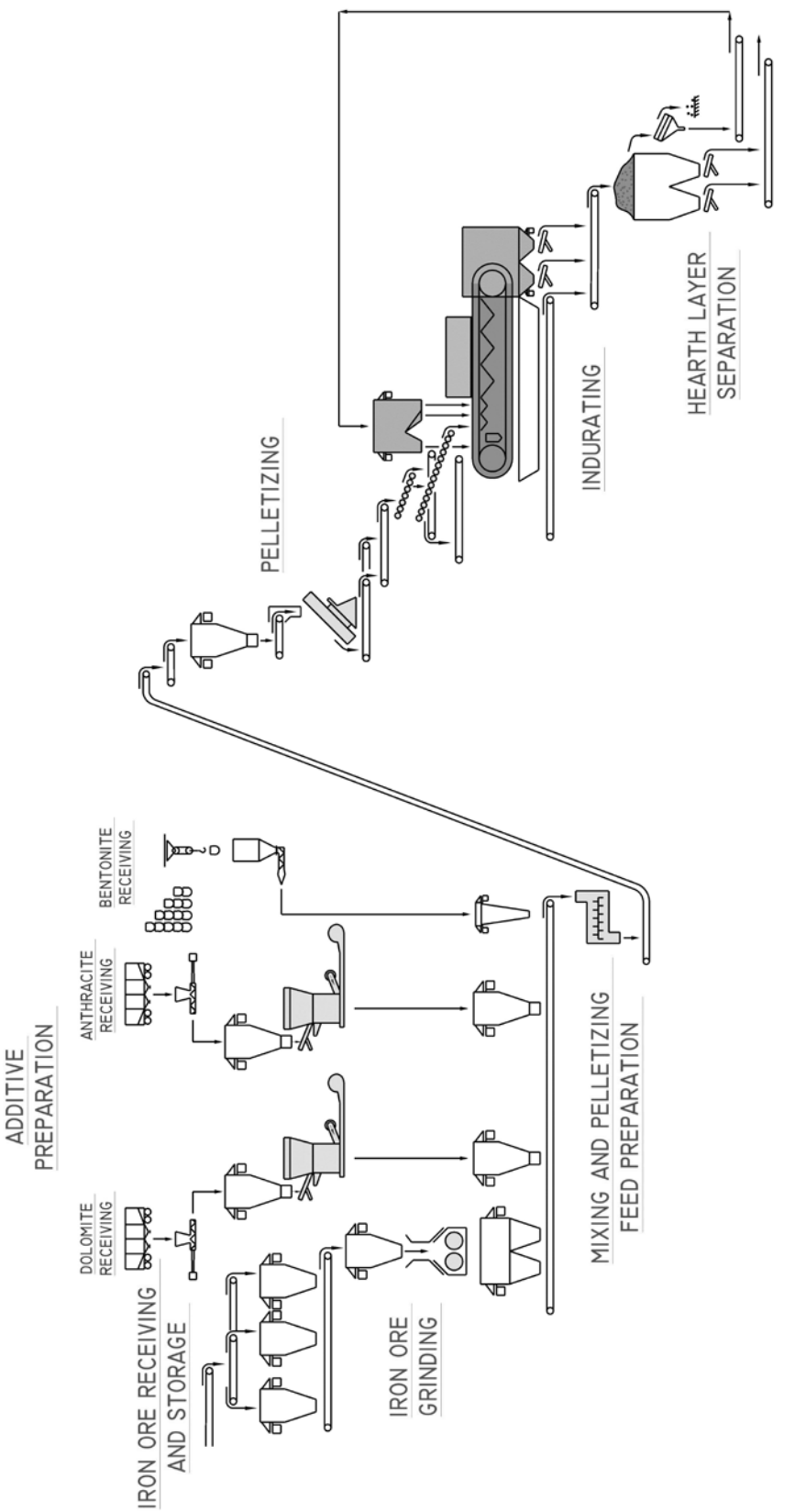
Modern plants can be designed to produce in excess of 7 million metric tonnes per annum of fired pellets depending on the design requirements and indurating process employed.

## Typical unit operations for iron ore pelletizing

An iron ore pelletizing plant is typically comprised of a series of unit operations in a specific process sequence. Below is a typical schematic for an iron ore pelletizing plant.

The typical pellet plant includes **feed preparation** where green pellets are produced. These green pellets are then fed to **indurating** for firing and hardening and producing the "fired pellets". The fired pellets are then transported to the last unit operation called **product handling**. Product handling is where the fired pellets may be screened for end user size requirements, or simply transported for storage and load out, or separated and recycled back to the **indurating** furnace if needed for further processing. Product handling is variable in nature depending on the end user requirements and indurating process employed. Note that in an iron ore pelletizing plant, the indurating process can be carried out by one of two technologies; (1) Grate Kiln technology and (2) Straight Grate technology. Both technologies are viable and proven, and are described in further details below as to when they are used and why.

## *Typical pellet plant schematic*



**Feed preparation** is the process that produces the green pellet. Feed preparation is the process that combines the iron ore with certain additives to achieve a very specific chemistry for the resulting fired pellet after indurating. Feed preparation for iron ore pellet plants is typically comprised of the following processes.

- *Additive preparation* – Depending on the criteria specified by the end user of the iron making furnace, additives will need to be combined with iron ore to produce the desired fired pellet chemistry. The quantity and type of additives are determined from laboratory testing. Typical additives for iron ore pelletizing are limestone, dolomite, coal or coke breeze, and bentonite. Bentonite is a binding agent for creation of the green balls. In some plants, alternate organic binders are used instead of bentonite. In order for the additives to be combined with the iron ore, they must meet a specific particle size requirement. If raw additives are delivered to the plant, they must be ground to proper size. This preparation is accomplished by using either air swept vertical roller mills or horizontal ball mills, depending on the capacity needs. Also, in some applications co-grinding of the limestone, dolomite and coal or coke breeze is appropriate. Bentonite must be ground separately due to significant density and hardness differences from the other additives. Depending on the feed preparation process, some of the additive grinding mills may not be required, since the additives can be co-ground with the iron ore grinding mills. Also, if the end user purchases pre-ground additive, additive grinding mills would not be required. These are all variables to be considered in the design.
- *Iron ore preparation* – Iron ore is supplied to the plant directly from the mine source or supplied from an external source. If the iron ore arrives properly sized and ground for balling (pelletizing), not much iron ore preparation is required. In this instance, the ore will be stored and handled for downstream processing. If not properly sized, the iron ore must be ground to pelletizing size. Iron ore for pelletizing is nominally 80% passing 325 mesh (44 µm), with a Blaine specific surface of between 1600 cm2/g and 1800 cm2/g. If a determination is made, via laboratory testing, that grinding is needed, grinding will be accomplished through the use of either a wet grinding process or a dry grinding process. The selection of the grinding process is determined by the type of ore, availability of water, and downstream process considerations. After grinding, the ore is stored in ground ore storage bins for the downstream processing.
- *Mixing* – Once the additives and iron ore are prepared, they are transported to the mixing area (building) via belt type conveyors where the materials are mixed and blended into a consistent material with a desired moisture content of around 10%, plus or minus some optimum amount. Mixing takes place in high intensity mixers, of either horizontal or vertical design. After mixing, the mixed ore is transported via conveyors to the balling process for making "green pellets".
- *Balling* - The mixed ore is transported to balling feed bins and then to the balling equipment which produces "green pellets" of a spherical shape and variable size distribution. The balling equipment is housed in a building called the "balling building". In the balling process, the moisture content of the mixed ore and resulting green pellets is optimized by the addition of water via spray nozzles or piping fixtures. The balling process is accomplished by metering a specific quantity of mixed ore from the balling feed bins via conveyors to the balling equipment. Typically, two types of balling equipment can be used, either balling drums or balling discs, each with their own unique operations. The nature and type of balling equipment produces the "green pellets" an

amazing process to be appreciated. After balling, the green pellets are transported to the Indurating process which produces the fired pellets, the end product.

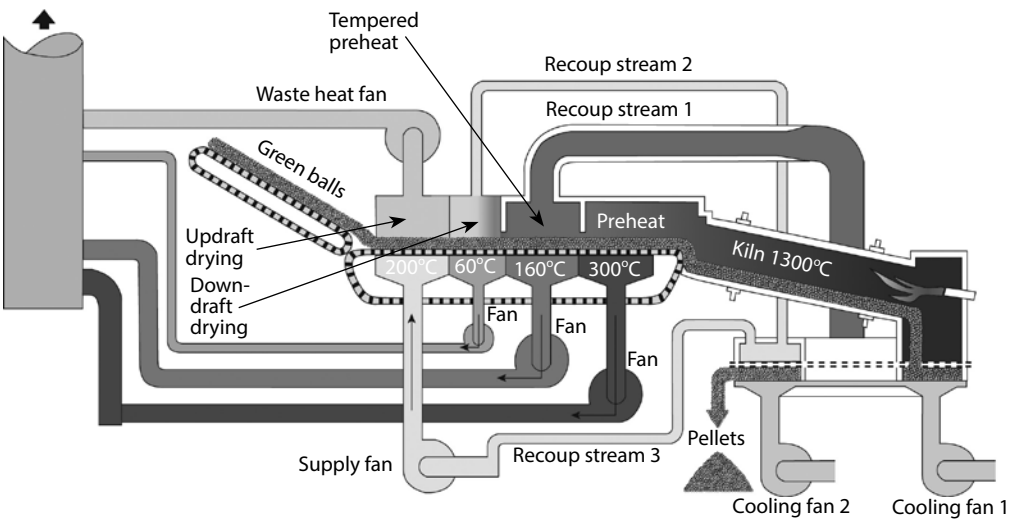
**Indurating** is the process of taking the green pellets and hardening them through a high temperature furnace application. The fired pellets are hardened such that they can withstand transportation and handling per the end user requirement. Details are as follows:

- *Machine feed* – After the balling process produces the green pellets, the pellets must be transported and fed to the indurating process. In most typical pellet plants, the green pellets are transported via conveyors from the balling process. This means of transportation is accomplished using, in sequence: (1) traditional belt type conveyors, (2) either an oscillating or reciprocating type conveyor for in-line or right angle feed, (3) a wide belt conveyor and (4) a roller screen which directly feeds the green pellets to the indurating equipment. The oscillating or reciprocating type conveyors layer and distribute the green pellets to the wide belt conveyor. The wide belt conveyor transports the pellets to a roller screen for removal of oversize and undersize pellets prior to feeding the indurating process.
- *Drying, firing and cooling* – After the pellets are fed from the roller screen, they are dried, fired and cooled. This is the indurating process. Two indurating technologies can be employed for this process; (1) Grate Kiln technology and (2) Straight Grate technology. The technology selected depends on the type and characterization of iron ore, the fuel, the desired fired pellet chemistry, and end user preferences. In both processes, the chemistry, physical properties and metallurgical properties of the fired iron ore pellets can be adjusted to suit the end user by combining the fine ore mixture with various additives prior to firing. The temperature profile in the indurating furnaces and processes can also be adjusted to influence the physical and metallurgical properties of the fired pellets over a wide range.



### *Grate Kiln technology*

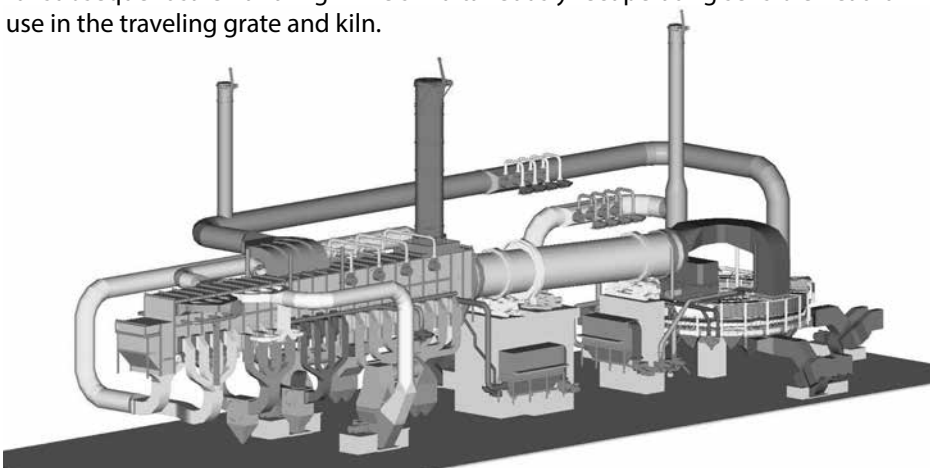
The Grate Kiln technology provides indurating through the use of a traveling mechanical grate for drying the pellets, a rotary kiln for firing the pellets and a rotating annular machine for cooling the pellets. The following is a typical schematic of the Grate Kiln process.



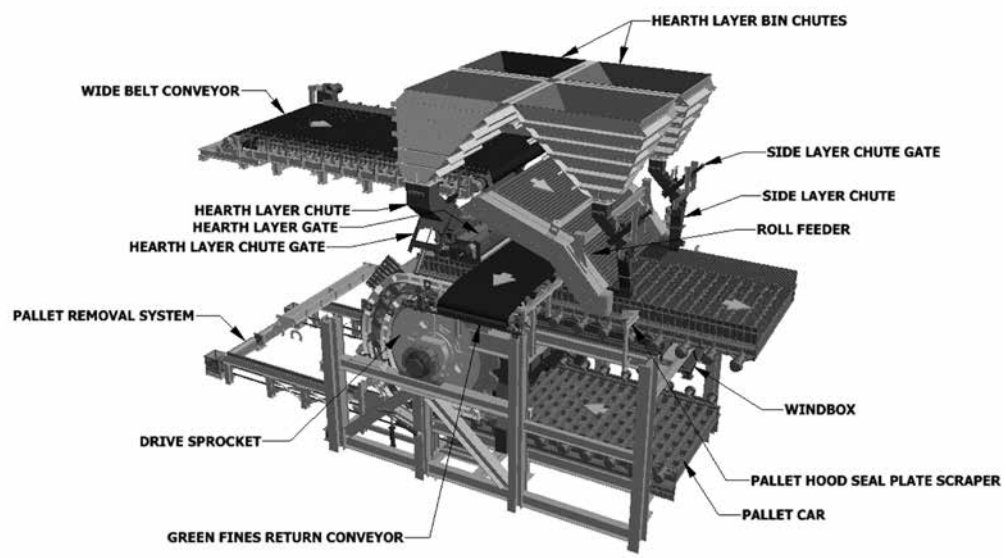
The traveling grate receives green pellets, removes pellet moisture through drying, and strengthens the pellet by preheating and subsequent partial fusion (induration) of the pellet's mineral bonds. After the drying and initial preheating in the traveling grate, the partially indurated pellets are fed directly into the rotary kiln, where the primary indurating (firing of the pellets) is accomplished.

The rotary kiln is a sloped rotating cylindrical furnace comprised of a burner at the discharge end. Through application of heat and uniform mixing of the pellet bed through tumbling as the kiln rotates, the rotary kiln heat-hardens and indurates the pellets, completing a unified formation of the mineral bonds. After the indurating process, the pellets are discharged to the annular cooler.

The annular cooler is a circular structure consisting of a rotating top and stationary bottom which receives the indurated pellets from the rotary kiln. It cools the pellets for subsequent safe handling while simultaneously recuperating sensible heat for use in the traveling grate and kiln.



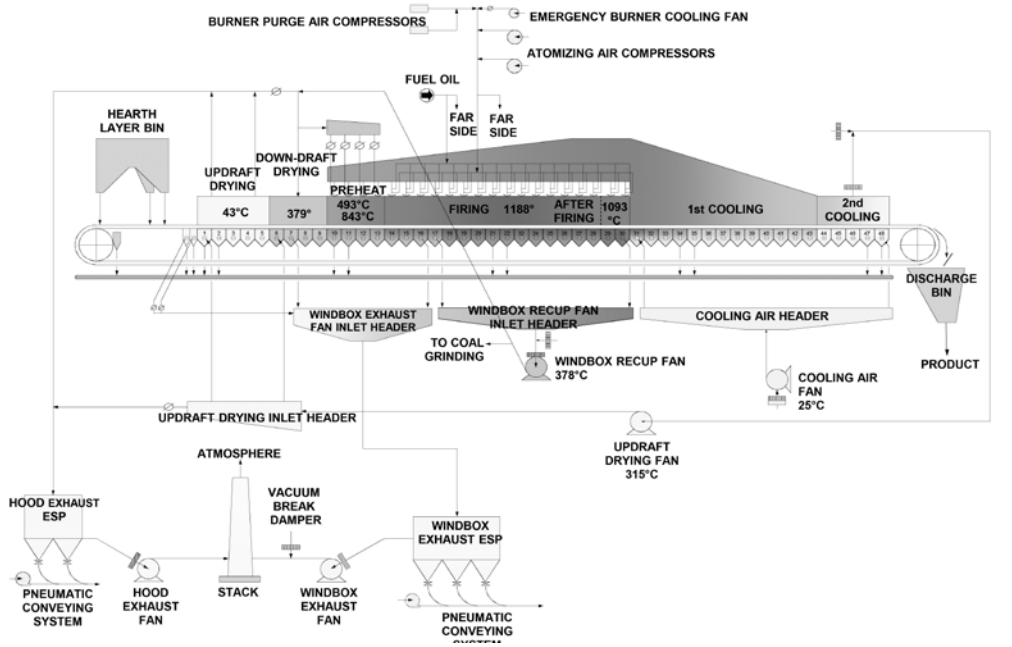
In the Straight Grate indurating process, the green pellets are dried, fired and cooled on a single strand consisting of a series of heavy cast steel pallets. The top surface of each pallet is made of an assembly of cast, high alloy grate bars which permit flow of process air through the bed of pellets. The green pellets are fed continuously to the indurating furnace at a depth of 300 to 400 mm. The following is a typical rendering of the machine drive and feed to the indurating furnace.

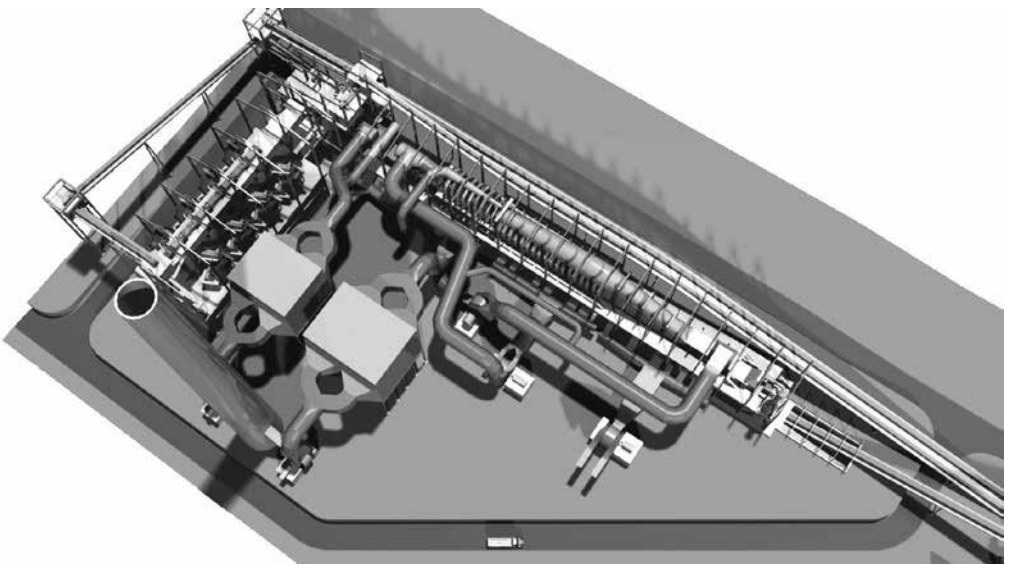


## Upgrading

The peak firing temperature required to harden the pellet is approximately 1350ºC. A typical design separates the furnace hood into six distinct process zones: up-draft drying, down-draft drying, pre-heat, firing, cooling and second cooling. Large fans are employed to move the process air streams from zone to zone. Fresh air is forced into the cooling zone to recover heat from the fired pellets prior to their discharge from the machine. This recovered heat is used to dry and pre-heat the pellets as well as furnish combustion air for the burners.

Heat for firing is provided by a series of burners entering through the side walls of the pre-heat and firing zones of the furnace. The burners can be fired with liquid or gaseous fuels. Burner fuel requirements can be reduced by mixing coal fines with the ore fines before forming the green balls. Air pollution control equipment is provided to control the particulate and gaseous emissions from the process stacks. The following are a typical schematic of the Straight Grate process and a rendering of a typical plant.



After the indurating process, the fired pellets are discharged to the **Product Handling** system. The Product Handling system typically includes a screening process for either mechanical or gravity separation of pellets by size.

If mechanical separation is used, vibrating screens are typically used to separate pellets into three categories: on-size, undersize and oversize. On-size pellets meet the requirements of the end user. Undersize and oversize pellets are collected for other downstream processes such as sinter feed or are recycled back into the indurating process.

Gravity separation is another commonly used process. Due to the nature of pellets in handling, oversize pellets typically migrate to the outer edges of storage bins or piles. By strategically placing chutes, oversize pellets can be diverted and separated in the process from on-size pellets. While this is a crude methodology, it works well in practice and is the least costly approach. If the client has very specific sizing needs, mechanical separation is the best approach.

Product handing for the Straight Grate process is slightly different than the Grate Kiln process. In the Straight Grate process, a portion of the fired pellets must be separated by size and recirculated back to the front end of the indurating machine, where they are layered on top of the pallets underneath the layer of green pellets. This layer of pellets, called the "hearth layer", is used to protect the pallets and grate bars from excessive temperature. These hearth layer pellets can be separated either mechanically or via gravity separation as described above.



## *Major process equipment components of iron ore pellet plant*

**Additive grinding mills** – Mills are required for the grinding of limestone, dolomite, coal or coke breeze, and bentonite. Additives are typically ground in either air swept vertical roller mills or horizontal balls mills, depending on the capacity needs. Also, in some applications co-grinding of the limestone, dolomite and coal or coke breeze is appropriate. Bentonite must be ground separately due to significant density and hardness differences with the other additives. Depending on the feed preparation process, some of the additive grinding mills may not be required, since additives may sometimes be co-ground with the iron ore. Also, if the end users purchases pre-ground additives, additive grinding mills would not be required. These are all variables to be considered in the design.

**Iron ore rotary dryers** - If a dry feed preparation process is designed, rotary dryers prepare the iron ore for feeding to the dry grinding mills by removing nearly 100% of the moisture from the ore.

**Iron ore grinding mills** – If the iron ore from the supply source is not properly ground to the proper size for pelletizing, ball type grinding mills are used. The ball mills are either dry grinding mills or wet grinding mills depending on the process design. Wet grinding mills produce a slurry for downstream filtration prior to the mixing process. Dry grinding mills produce a final grind directly suitable for feeding to the mixing process.

**Filtration equipment** – If a wet grinding process is utilized, filtration equipment is supplied to remove water from the iron ore slurry emanating from the wet grinding mills. Depending on the chemical characterization of the iron ore, either Vacuum Filters or Pressure Filters are used. Pressure filters are used commonly when the ore has a high content of alumina (clay) type constituents. Filtration tests are done on the ground ore to determine the applicable filtration equipment.

**Slurry handling equipment** – The wet grinding process requires equipment to pump, store and thicken the slurry prior to filtration. Rubber lined pumps transport the slurry to and from large slurry storage tanks, a concentrate thickener, and eventually the filtration equipment. A concentrate rake type thickener is used in the process to increase the density of the slurry prior to filtration.

**Mixer** – Mixers are utilized to blend individual pelletizing feed components, iron ore and additives to a homogeneous balling feed. Typically two types of mixers can be used for this process; (1) horizontal rubber lined paddle type mixer, or (2) vertical type bowl mixers with hardened components. Both are equally suitable.

**Balling disk or balling drum** – A balling disk is a rotating mechanical platform (dish or disk in form) with retention rims to hold and process material. A balling drum is an inclined cylindrical machine (barrel like vessel) that rotates. Both equipment types receive a finely ground mixture of iron ore and other additives and produce uniform spherical pellets through the addition of moisture and the dynamic forces of rotation or circulation.

**Balling disc roller screens** – Roller type screens are used to separate on-size and off-size green pellets. The off-size materials are recycled, shredded and re-processed through the balling process. On-size pellets are conveyed to the indurating process.

**Conveying equipment** – Iron ore pellet plants are heavily dependent on belt conveyors for the transfer of bulk materials and pellets from one unit operation to another.

**Reciprocating conveyor mechanism** – A layout having the balling building at a right angle to the indurating machine will require the use of a reciprocating type conveyor. The discharge pulley at the end of a belt type conveyor moves back and forth, distributing a layer of pellet across the width of the wide belt conveyor. By means of varying the speed of the reciprocating stroke and pulley speed, and the wide belt speed, a relatively even layer of green balls is spread across the wide belt conveyor.

**Oscillating conveyor** – A layout having the balling building in line with the indurating machine will require the use of an oscillating type conveyor. The green ball oscillating feed conveyor receives unfired green ball pellets from the balling disc belt conveyors, and then transfers and distributes the pellets onto the wide belt feed conveyor via an oscillating mechanism. The wide belt conveyor is oriented in line with the oscillating conveyor. By varying the speed of the oscillating head and the wide belt speed, a relatively even layer of green balls is spread across the wide belt

**Wide belt conveyor** – The wide belt conveyor receives green pellets from the oscillating conveyor or reciprocating conveyor and delivers the pellets to the indurating machine feed roller screen. The wide belt conveyor is a non-standard belt conveyor that, due to its extreme width and belt loading, requires special design considerations and components.

**Machine feed roller screens (single deck or double deck)** – The green balls are fed onto a roller screen where a series of rotating rollers separate and transport the green pellets to the indurating machine (process). Depending on the capacity of the plant and end user needs, either a single deck roller screen (SDRS) or double deck roller screen (DDRS) is used. The number of rolls is dictated by the capacity of the plant and the final fired pellet sizing requirements. The rollers screens are operated by a variable speed drive which alters the speeds of the rolls and optimizes the screening efficiency.

- For the SDRS, the roller screen separates on-size pellets from under size. The undersize pellets fall through the gaps set between the individual rolls. The undersize pellets are shredded and recycled back through the plant for re-balling. The on-size pellets, all pellets having a diameter larger than the gaps, are fed to the indurating machine.
- For the DDRS, two separate roller screen or decks are installed, one called the top deck or oversize roller conveyor, and the other deck called the bottom deck or machine feed roller conveyor. The oversize roller conveyor has gaps set to the largest fired pellet size required by the user, and the machine feed conveyor has gaps between the rolls set to the minimal size of pellet. The oversize pellets are conveyed via rollers to an oversize belt conveyor perpendicular to the roller deck. The oversize belt conveyor feeds into the shredder which reduces the oversize to fines for recirculation back to the balling circuit. On the machine feed roller conveyor, the on-size material is separated from the fines material. The fines material falls through the gaps between the rollers onto the fines belt conveyor(s) located under the machine feed roller screen. The fines are also recirculated to the balling circuit. The "on-size" material discharges directly into the indurating machine.

**Indurating machine** – Depending on the indurating process employed, either the Grate Kiln indurating process or Straight Grate indurating process will be used. As described above, each process has specific equipment tailored to the process.



**Process fans** – Both the Grate Kiln and Straight Grate processes use a series of large process fans to move and distribute ambient air and hot process gases through the systems. These fans have specific process requirements which dictate the capacities and sizes of the fan. In general, fans are sized, if possible, to a common size to minimize spare parts needs.

**Air quality control equipment** – Dust collection and emissions controls are provided for each pellet plant based upon the end user needs to satisfy the applicable emissions regulations. Baghouses, electrostatic precipitators, scrubbers, and even more complicated equipment are used.

### *Design criteria and plant sizing*

The iron ore pelletizing plant, design and sizing, is affected by many factors which are evaluated during the upfront engineering process for the project. Each project is typically unique to the design criteria, however many plants can be similar in nature. Although plant capacity (i.e. million tons per annum, mtpa), is a commonly used identifier, the details of the design criteria typically vary quite a bit. The following are design criteria that must be considered in the development of a pellet plant design.

**Plant Location** – Site locations set the ambient conditions for temperature, site elevations, soil bearing capacity, wind conditions, seismic zone and other factors. This affects sizing of equipment and design of structures. The terrain of the site is also important in setting the orientation and configuration of the plant to take advantage in any changes in elevation on the site.

**Fired Pellet Chemistry** – The end use determines the type of fired pellet needed, such as blast furnace (BF) pellet or direct reduced iron (DRI) pellet. Each pellet type sets the iron content of the fired pellet and chemistry, resulting in the quantity of additives needed to produce the end product.

**Raw Material Supply and Characteristics** – The type of iron ore and additives and their characterization set the plant design requirements. Is the iron ore as received, properly ground for pelletizing? Will the additives delivered be pre-ground or will on-site grinding be needed. Is the iron ore a magnetite or hematite ore, and what is the iron content (Fe) of the ore? What are the silica and alumina content of the iron ore? What is the type of fuel to be used to create the heat input to the indurating process. There are many questions to be asked. These help determine the overall process and what type of indurating process to be used. This information is used to tailor the chemistry of the pellets to produce desired metallurgical and physical properties in the fired pellets.

**Iron Ore Testing Programs** – A most critical part in the upfront engineering of a prospective iron ore pelletizing plant project is the iron ore testing program. For iron ore pellet plants, the testing program is called "Pot Grate Testing". These unique testing programs have been developed for fired pellets produced using the Grate Kiln indurating process or the Straight Grate indurating process. These testing programs can take up to three to four months to perform after receipt of the raw materials to be tested. Pot grate testing is the basic tool to determine the optimal firing pattern (temperature profile and process gas flows) within the indurating process to achieve the specified production rate and product quality for the raw materials being supplied. The pot grate testing allows the plant to be designed for the lowest capital, operating and maintenance costs.



## *Comparisons of indurating technologies*

Iron ore pelletizing plants are similar in the various unit operations making up a typical plant. The one main variable is the type of indurating unit operation utilized. The following are some comparatives between the two processes in respect of capital cost investments, operations and maintenance.

**Capital cost comparison**

| Straight Grate | Grate Kiln |
|---|---|
| • Overall indurating machine length is similar<br>• Slightly narrower width<br>• Similar total plant area when balance of plant is considered | • Overall indurating machine length is similar<br>• Slightly wider width<br>• Similar total plant area when balance of plant is considered |
| • Balling area is lower (elevation) because entire machine is at one elevation | • Balling area is significantly higher (elevation) so as to feed traveling grate |
| • Less structural steel required because of lower balling area elevation | • More structural steel required |
| • Lower capital cost by about 10% | • Higher capital cost |

**Operation comparison**

| Straight Grate | Grate Kiln |
|---|---|
| • Capable of firing gas, or liquids (no solid fuels) | • Capable of firing solid fuel, gas , or liquids |
| • Higher electrical power consumption due to deep bed of pellets | • Significantly lower electrical power consumption |
| • Fuel consumption is similar<br>• Single machine | • Fuel consumption is similar<br>• 3 separate machines – traveling grate, kiln, annular cooler, allows control of residence time in each |
| • Multiple burners provides process flexibility | • Single burner in kiln, additional burners in traveling grate when processing hematite |

**Maintenance comparison**

| Straight Grate | Grate Kiln |
|---|---|
| • Pallet cars can be taken off-line for maintenance | • System must be shut-down for maintenance |
| • Pallet cars made of alloy steel parts | • Grate chain and all plates are made of alloy steel parts |
| • Less refractory maintenance | • More refractory maintenance, but done at annual shut-down (mostly kiln) |
| • Single machine, one drive to maintain | • 3 separate machines – traveling grate, kiln, annular cooler, 3 drives to maintain |

## *Lime calcining system*

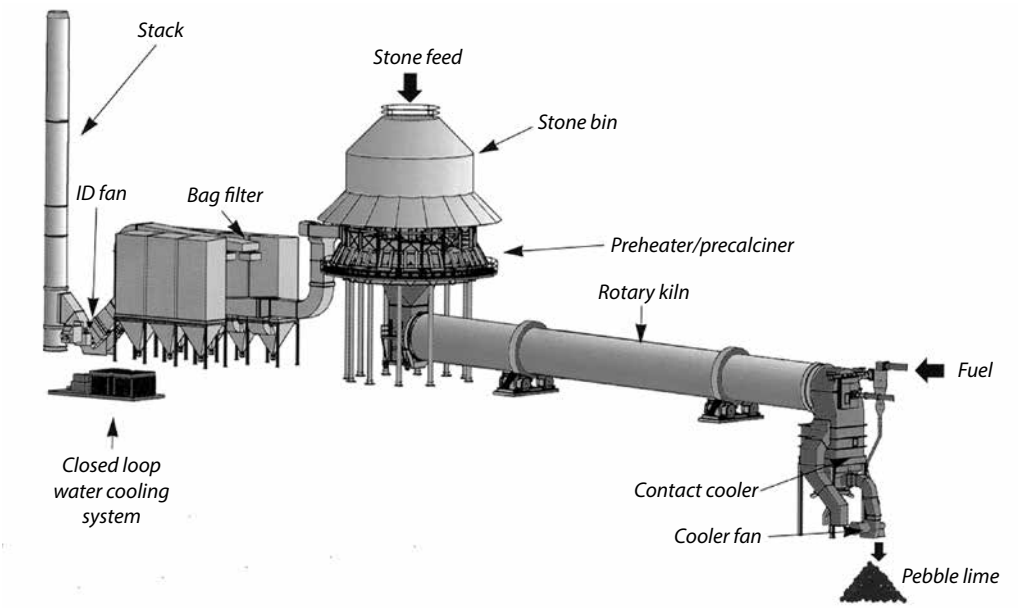
The preheater-rotary kiln system calcines a medium to small size limestone, is capable of high production capacities, and produces a uniform, high quality lime product. The "straight" or "long" rotary kiln (one without a preheater) uses a greater amount of fuel per tonne of product.

### *General arrangement*

A preheater-kiln system includes a stone bin, preheater, rotary kiln and stationary cooler. Calcining begins in the preheater and is completed in the rotary kiln. Heat transfer in a preheater-rotary kiln system is "counter-current". The limestone/lime material travels through the system in one direction and the hot process gases that provide the necessary heat for calcination travel through the system in the opposite direction. The preheater recovers heat from the kiln exhaust gases and the cooler recovers heat from the lime as it discharges from the kiln. The heat recovered from the cooler is used in the kiln as preheated combustion air.

The following figure identifies the major components of a typical polygon preheater-rotary kiln system with coal firing and a "baghouse" type dust collection system. This configuration is typical of lime plant installations in North America, in particular, where regular solid, alternative solid, liquid and gas fuels are plentiful and in turn, relatively inexpensive. In addition, baghouse style dust collection is used nearly exclusively in order to comply with the strict limitations on particulate emissions imposed by the governing agencies.





## *Process and equipment description*

Limestone feed is delivered to the un-insulated, carbon steel stone bin, on an intermittent basis, by an appropriate stone preparation and conveying system. It enters the stone bin through an opening at the center of its roof, and is directed to a series of equally spaced discharge points in an annulus at the bottom of the bin. Limestone leaves the stone bin, by gravity, through a set of stone chutes and enters the integral preheater unit, directly below, replacing partially calcined material as it is discharged from the preheater at a controlled rate.

The refractory-lined preheater is made-up of a series of adjoining compartments, or modules, arranged in something of a circular shape (in plan) with a common discharge hopper at the center. Each preheater module receives stone through a four-sided, vertical chute that connects the module to a corresponding discharge opening in the stone bin directly above. These chutes, which are always full of stone during normal operation, create an adequate seal between the process gas stream within the preheater and ambient (at the stone bin inlet). Hot process gases are pulled through the bed of material in the preheater by an induced draft fan (or I.D. fan). The heat content of the gases entering the preheater is such that calcining begins in the preheater. Once through the material bed, having transferred much of the heat to the material, the gases exit the preheater through two exhaust gas manifolds.



Partially calcined material, which has been raised from the near ambient temperature of inside the stone bin to around 760 °C, is pushed from the sloped floor of each module into the center hopper of the preheater by a discharge plunger within the module. Each of these plungers is moved through its stroke cycle by plunger rods connected to a hydraulic cylinder drive mechanism. The alloy steel plunger castings are the only non-refractory lined components found within the preheater.

The partially calcined material passes through the transfer chute and enters the refractory lined rotary kiln, which is installed on a gradual slope away from the transfer chute. Material travels from the upper to lower end of the rotating kiln, while hot process gases are pulled through the kiln in the opposite direction. It is here where the calcining process is completed.

Calcined lime falls from the discharge of the rotating kiln, through discharge grates at the base of the firing hood into the cooler.

As the name implies, it is the firing hood that provides the insertion point for the single burner of the kiln firing system. After passing through the grates at the base of the firing hood, the calcined lime falls into the cooler. Viewed in plan (from the top), the cooler is square and is divided into four cooling compartment, or quadrants. Air is forced into the cooler by the cooler fan. This air cools the lime in counter-current flow through the cooler and then travels up through the cooler grates into the firing hood and kiln, where it serves as preheated secondary combustion air for the firing system

## *System capabilities / flexibility*

**Limestone Feed**

Systems has been designed for limestone feed sizes as large as 75 mm, but a more typical maximum top size is 60 mm. Systems have also been designed for feeds as small as 6 mm, but, again, the more typical minimum bottom size is 9 mm. In order to maintain a reasonable pressure drop across the packed bed of material in the preheater, a maximum top-to-bottom size ratio is required. This design feed size ratio if most often a maximum of 4 to 1. However there are preheater-kiln systems in operation today successfully processing stone feed size fractions with top-to-bottom size ratios of 6 or even 7 to 1. Feed size ranges this broad, of course, help to minimize stone cost by maximizing utilization of the quarried stone.

**Fuel types**

Because a single burner supplies the process heat to the calcining system, a firing system can easily be designed to handle any of the commonly available forms of fuel–solid, liquid or gaseous. The system can be designed to fire a single type of fuel, or a combination of fuels. There are also designed systems for plant sites around the world that use fuels such as fuels oils of various grades, natural gas and coke oven gas, among others.



**Fuel rates**

The greater the rated capacity of a preheater-kiln system, the less fuel it will consume per tonne of lime product. This is simply because there is less equipment surface area available for system heat loss, per tonne of product, at higher system production capacities. The expected nominal fuel rate for an 1100 metric ton per day preheater-kiln system would be in the range of 1000-1150 kcal/kg of lime (4185-4815 kJ/kg), net basis.

**Lime product quality**

The combination of the preheater and the rotary kiln working together produces an extremely homogenous lime product of very high quality. In the preheater the finer size particles are calcined more completely than are the coarser particles. In the rotary kiln, because the finer material is trapped in the "kidney" of the rotating bed, somewhat isolated from the hot process gases as it travels through the kiln, the opposite is true. The end result is that by the time the material reaches the discharge end of the rotary kiln all of the material is calcined to the same extent. In addition, because limestone feed to the system is typically no larger than 60 mm, each piece of material can be calcined thoroughly, leaving only small amounts of residual $CO_2$ in the material, when required. The preheater-rotary kiln system is capable of producing limes with a residual $CO_2$ as high as 3.0% and a high reactivity, and as low as 0.01% – basically dead burned.

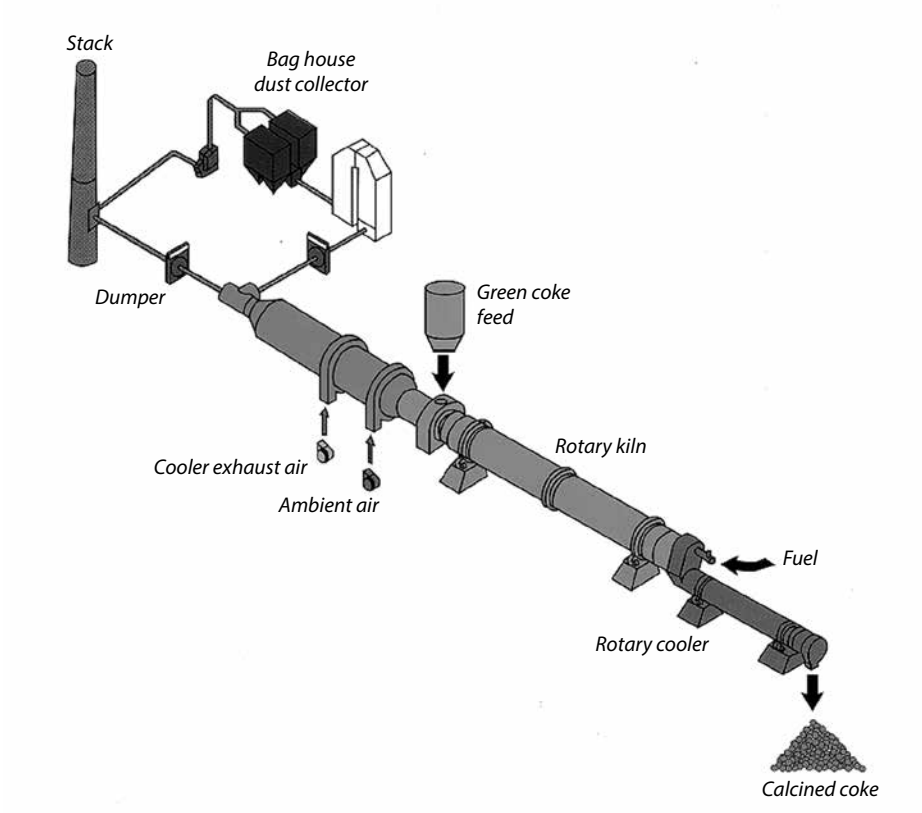
The preheater-rotary kiln system is also a proven means of producing steel industry grade–low sulfur–lime. Sulfur capture by the material as it travels through the calcining system is a mass transfer phenomenon, which takes place when sulfur in the process gas stream is in intimate contact with the material. Since the preheater-kiln system maintains a relative short packed bed of material (relative to other types of kiln systems) in the preheater, little opportunity is provided for the transfer. In addition, if a fuel is used that has a sufficiently low sulfur content, some of the sulfur entering the system in the stone can be driven off in the firing zone of the rotary kiln. This sulfur can then attach to the very fine material in the process gas stream and, once through the preheater, be collected .

## *Coke calcining system*

Petroleum coke (green coke) is a solid residue by-product from refining oils, gasoline and other hydrocarbons. The green coke is removed from a coking drum used in the refining process. The main components of green coke are carbon and volatile compounds. Coke calcining is a process where green coke is converted (by evaporating the volatiles) into nearly pure carbon that is used (mainly) in the production of aluminum. This technology became prevalent in the 1940's and 1950's (when aluminum started to find favor with manufacturers).

The raw, green coke is fed into the rotary kiln where it is calcined using heat from the main burner as well as heat from burning dust and volatiles released from the coke inside the kiln. There is sufficient temperature in the kiln to burn the coke; so, the oxygen content in the kiln must be controlled very carefully to prevent all of the coke from burning. Air is injected through the shell of the kiln to burn a portion of the volatiles released from the coke and provide heat for the calcining process. The calcining process drives off most of the volatiles from the coke. These gases flow up the kiln and enter the afterburner where additional air is injected and the volatiles are burned. The heat energy in the afterburner exhaust gas is recovered in a boiler (to make steam for the refinery or to make electrical energy). The calcined coke travels through the kiln and exits into a cooler where the product temperature is lowered using water quenching or contact cooling. From there, it is taken off to a storage silo.





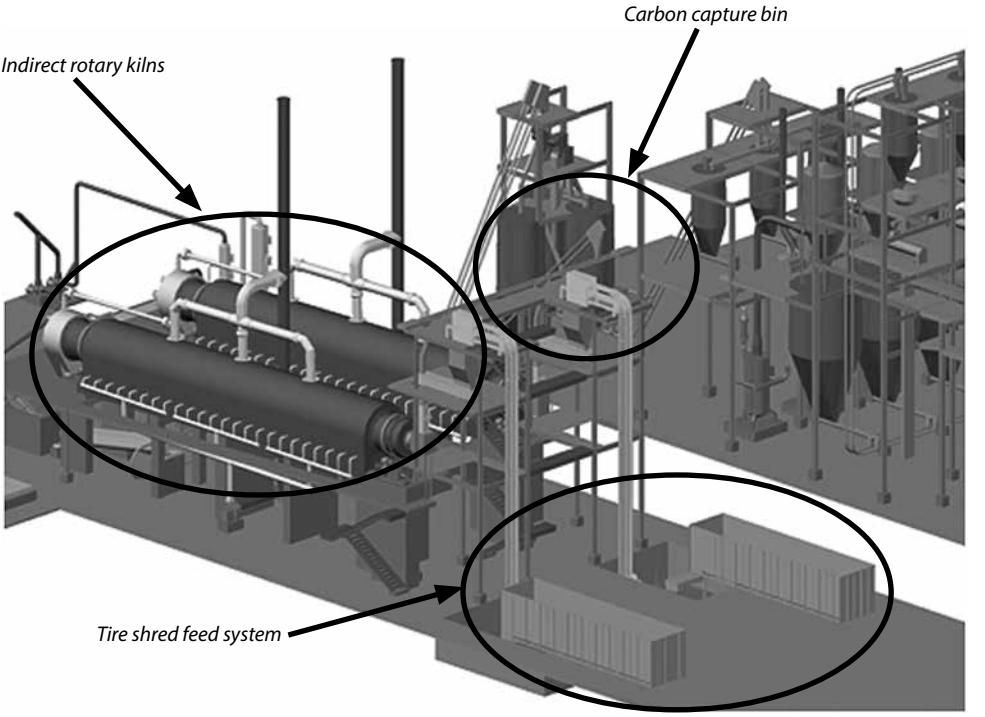
## *Tire pyrolysis*

Worldwide, it is estimated that one billion scrap tires are produced every year. Have you ever wondered what happens to all of these scrap tires?

In the US, the majority of tires are used as a supplemental fuel source. The heating value per pound of tires is slightly higher than coal. Cement kilns, waste incinerators and boilers for paper mills are the biggest users (mainly because they can easily handle the leftover metal radials). The second biggest user of scrap tires is the asphalt industry. In the end, however, an estimated 9% of scrap tires (26 million tires per year) end up in a landfill. Worldwide, we know this percentage is much higher, especially in developing countries like China and India. That leaves some 100 million tires ending up in a landfill where they will remain for a long, long time.

To maximize the economy of recycling tires, a process has been developed where all major components of the tire can become revenue streams (money generators) for the recycler. This means making use of the steel, carbon black (major component of the rubber) and the fossil fuel components of the rubber (specifically the oil). These are the big three. Instead of burning the tires, they are roasted at a lower temperature in an atmosphere devoid of oxygen (so that no actual burning occurs). This method of roasting is called pyrolysis, and is used for many different processes. By using pyrolysis, the tire shreds can be broken down into their three basic components (carbon black char, steel radials and oil/gas). Since the three off-coming streams can be captured and sold, the recycling process becomes profitable and not just possible!

The figure below shows the basic tire pyrolysis system...



Shredded tire chips approximately two inches by four inches are received at the recycling facility. The chips are fed to an indirect rotary kiln using special conveyors. In the indirect kiln, the pyrolysis reaction is carried out. Remember, an indirect kiln adds heat from outside (through the shell) and there is no direct flame inside the kiln. This is done because no oxygen can be present for the pyrolysis reaction to correctly occur. The chips go through three stages inside the kiln. First, the rubber becomes brittle and separates from the steel (we call this the rubber char). In the second stage, the oil and gas are forced from the rubber char and collected.
In the last stage, the char is fully processed into a carbon black-like substance and separated from the steel wires. The char is sent through a holo-flite processor (to cool it) and then sent to a bagging system where it is packaged for transport.

The steel is cooled in an air dryer and the steel wires are compacted and shipped to a steel recycler or steel processing furnace. The off-gas from the kiln is pulled through a patented condenser where oil is extracted. This oil is very similar to a diesel fuel. In addition, there is a gas stream of non-condensable oil that can be sent to a boiler and used for generating steam (for heating or power generation).

From a single tire, approximately 1/3 of the mass recovered is steel, 1/3 becomes carbon black and the other 1/3 is oil. Hundreds of hours of continuous testing and processing of thousands of pounds of tire shreds has been conducted to learn the correct method for heating the tires, the best method for handling the shreds, the best method for handling the wires and also the best configuration for the oil condenser. Many technological hurdles have been crossed through this testing (such as preventing pluggage in the condenser, tangling of the chips as they enter the kiln and effectively cooling the rubber char).

## Introduction

In the process stages of size reduction, size control, enrichment and upgrading the values of the minerals or rock are brought to their optimum.

We will now look closer into what forms these process stages into a continuous operation.

***With materials handling we understand the technologies for moving the process forward with a minimum of disturbances in capacity and flow. These technologies are:***

- Loading and unloading
- Storing
- Feeding
- Transportation

For practical reasons we are using the term materials handling for dry processes only.

*Of course, the technologies for moving a wet process forward are equally important. We call this slurry handling and the subject will be covered in section 8!*

## Loading and unloading

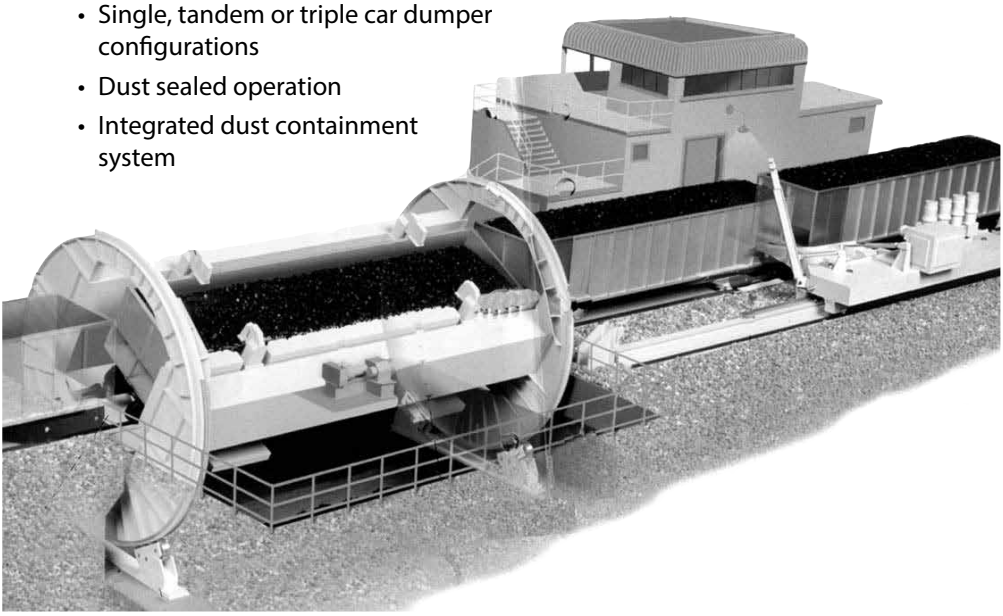
In this section we will only cover loading and unloading conditions related to rail cars and sea vessels (high capacity conditions)

## Railcar dumpers

Rail is the most common inland way of hauling large quantities of raw ore, upgraded minerals and coal etc, and unit trains up to 200 rail cars have to be unloaded during shortest possible time observing safety and environmental requirements.

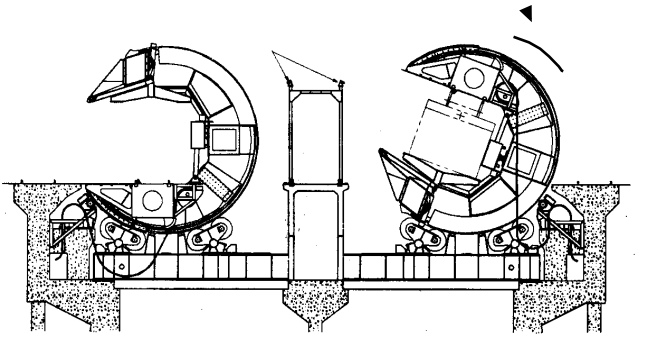
### Railcar dumper – rotary type

- Reliable and proven design
- Capacities up to 100 cars/h
- Single, tandem or triple car dumper configurations
- Dust sealed operation
- Integrated dust containment system



### *Railcar dumper – "Crescent" design*

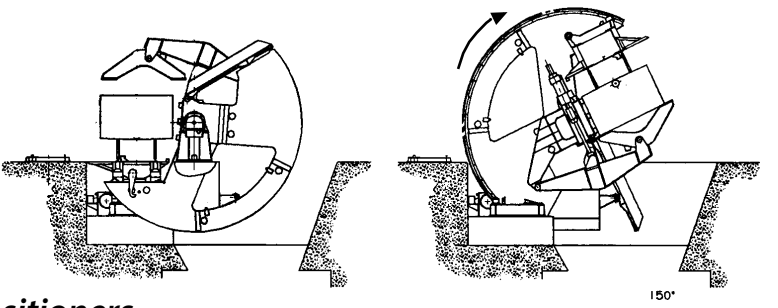
- Low in energy (rotation axis close to gravity centre of loaded cars)
- Hopper position close to rail track
- Hydraulic car clamping system (closed loop)
- Rate of unloading 60 cars/h and line



### *Rail car dumper - Rotaside® type*

- Hopper position at the side of rail track gives simplified installation
- Proven and simple design
- Low in maintenance
- Rate of unloading 12 cars/h

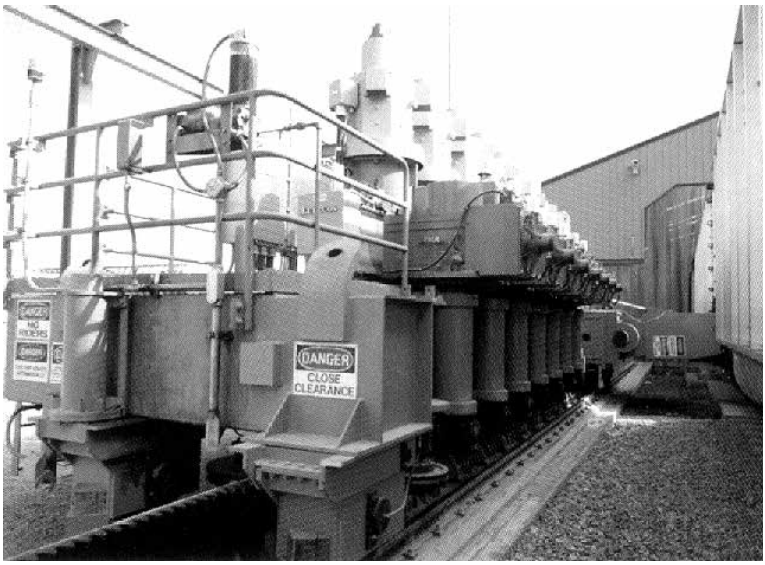





## *Train positioners*

A train positioner has to have a high utilization capability to enable it to precisely position blocks of 1-10 railcars up to heavy train in excess of 200 railcars using a preset velocity pattern. In duties ranging from 5 to 90 cars unloading per hour there are a number of options for positioners.

| System | Unloading duty |
|---|---|
| Side arm system (rack and pinion drive), see picture nest page | Heavy 100 car, or more, trains at high capacity |
| Reversible hydraulic indexer system | 25 ton pull, 5-15 cars/hour |
| Wire rope car pullers | From 2-12 ton pull at variable speeds |
| Vertical capstan system | Manual operation - limited pull and distances |
| Double side arm system (Gemini®) | For very high unloading rates |




*Side arm system*

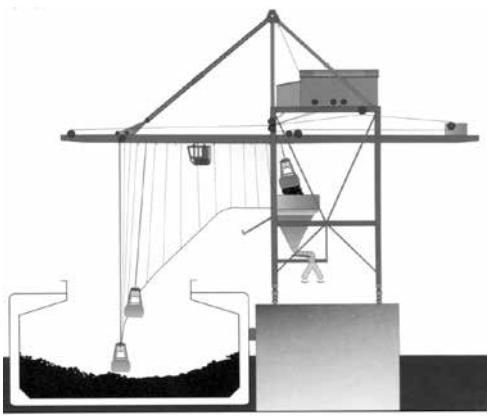
## *Unloaders*

### *Grab unloader*

Grab unloading is a classical way of unloading ships and barges. This concept is still valid but has undergone a massive development.

Today's high speed grab unloaders feature short duty cycles and large capacity buckets for greater unloading volume and efficiency.

- Reliable equipment
- Low operating costs
- ABC system (Automatic Bucket Control) with grab control on closing,
  filling, loading and positioning
- Integrated dust containment system



**Unloading capacities (typical)**

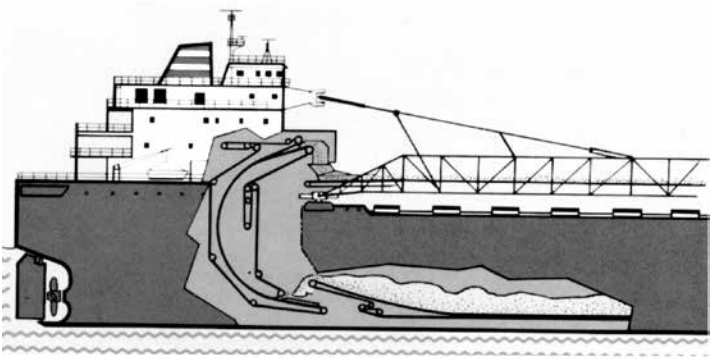
- Grab capacity coal 6 to 25 tonnes
- Grab capacity iron ore 6 to 40 tonnes
- Duty cycle: 36 to 45 sec
- Free digging rate coal 500 to 2000 tonnes/h
- Free digging rate iron ore 500 to 3 400 tonnes/h

## *Continuous unloading*

For high capacity unloading applications (for faster ship or barge turnarounds) continuous unloading is an option.

**CBU** (Continuous Barge Unloaders) and **CSU** (Continuous Ship Unloaders) can be manual, semi automatic or fully automatic "Self-Unloading" systems of type

- Inclined bucket elevator
- Loop belt system
- Vertical conveying system see also conveying, page 7:16 and 7:21
- Capacities up to 6 000 tonnes per hour
- Operator friendly, less polluting operation (dust & noise)
- Long service life
- Flexible in sizes and capacities

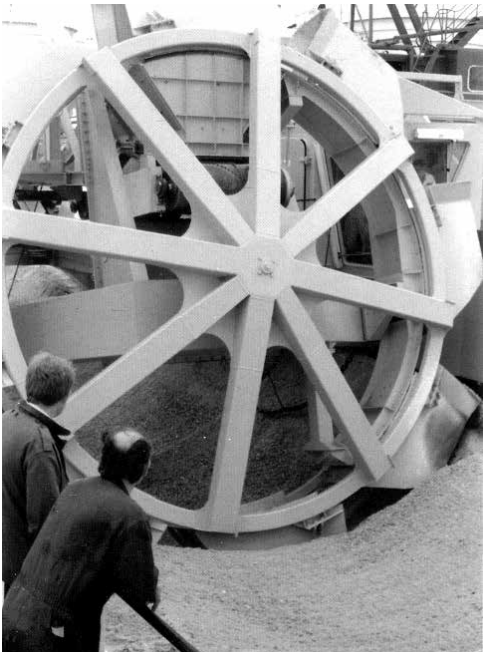


*Loop Belt System*



## *CSU- bucket wheel type*

- Optimal for unloading sea dredged sand or other suitable bulk material.
- Varying number of buckets to suit vessel size (1 400-4 500m$^3$)
- Discharge rate to shore 1 200 m$^3$/h
- Bucket wheel protected in "sea position"



# Storage buffering

Buffer storage is some time called "the key to processing", meaning that without a proper storage throughout a continuous rock or mineral process, production up-time will be gone.

## Storage in operation

The main purpose of storage is to smooth out:

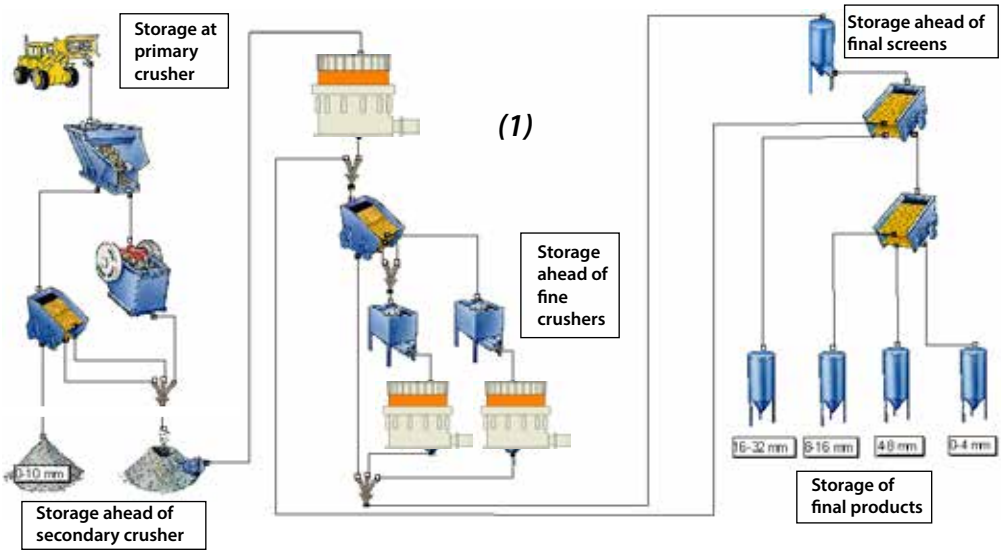
- Different production rates (cont cyclic)
- Shift variations
- Interruptions for repair
- Size variations
- Flow variations
- Variations in mineral value (metal content etc.)

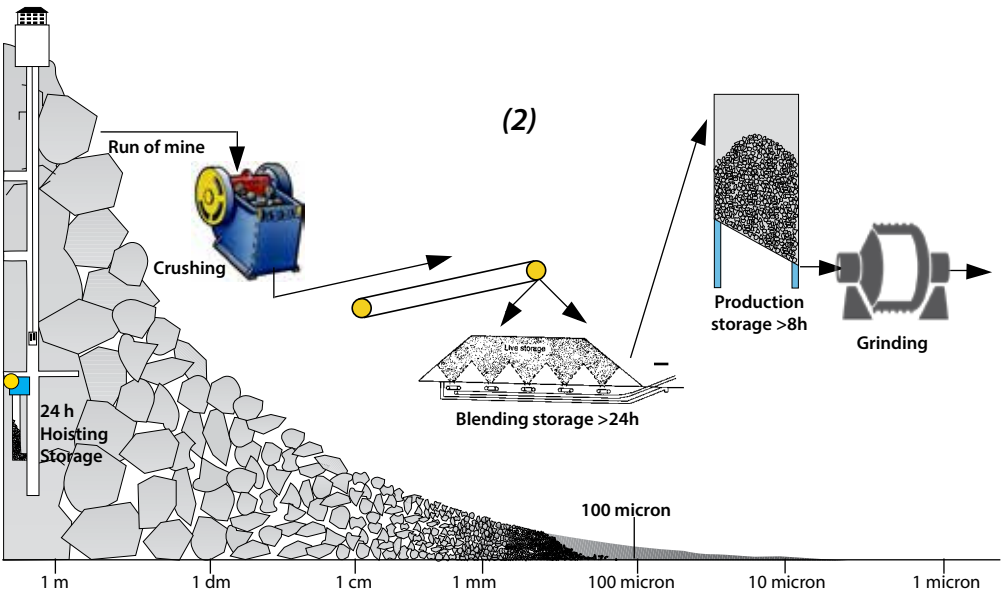
## Storage of rock (1)

A matter of material flow (retention time)

## Storage of ore and minerals (2)

A matter of material flow (retention time) and blending



## *Stacker reclaimer*

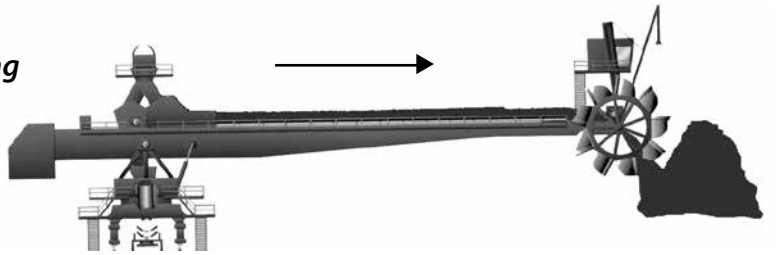
Large storages with high capacities for feeding mineral processing plants, combustion plants (coal),ships etc. cannot use loader and truck technology. Here effective stacker reclaimers are the only option

**Trenching type** stacker reclaimers are used for low-volume, high active storage capacities between 30 000 and 60 000 tons. Reclaiming operations are accomplished by longitudinal pass through the pile.
Stacking and reclaiming rate usually vary from 2 000 - 4 500 tons per hour.

**Slewing type** stacker reclaimers are typically used where large quantities of material must be readily available, where blending of material grades is required and where yard length is limited.

Stacking and reclaim rate up to 6 000 tons/h for coal and 8 000-10 000 tons/h for iron ore.

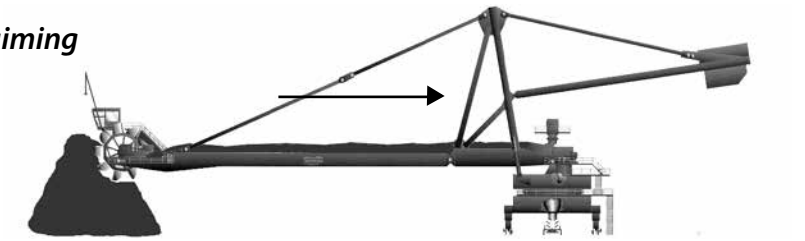
***Stacking***



*Straight-through boom configuration max length 38 m*



***Reclaiming***



*Masted boom configuration length over 38 m*

## *Scraper reclaimer*

These reclaimers are designed to handle materials as (typical) phosphate, coal, sulphur, fertilizers and woodchips servicing parallel storage piles from booms mounted on either or both sides of the machine.

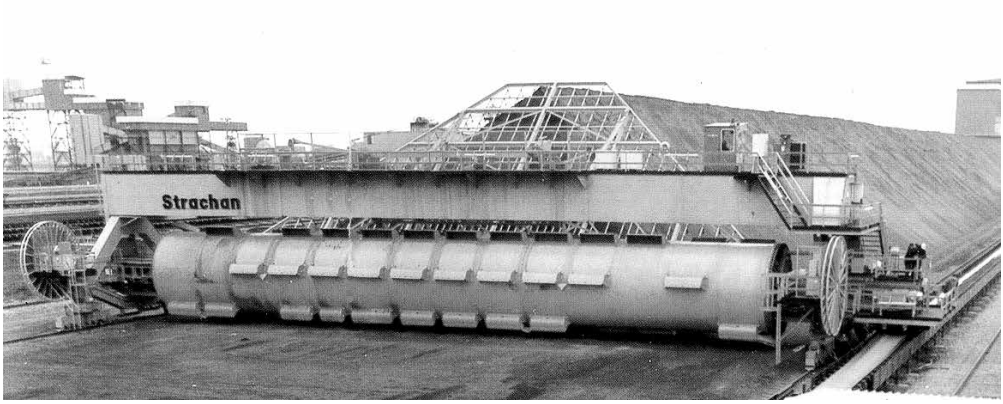
They incorporate the cost advantage of "back stacking" (the ability to reverse boom flight direction up the storage pile).

- Capacities up to 4 000 tons /h
- Single, twin and double-boom options

## *Barrel reclaimer for "Full cross section recovery"*

The optimal machine reclaiming from a blending pile is the barrel reclaimer. The heart of the machine is a rotating barrel fitted with a large number of buckets. Material collected in the buckets is discharged into an internal conveyor feeding a downstore conveyor running alongside the pile.

- Very robust a reliable design for high capacities · Variable speed for differing reclaim rates
- Automatic operation (optional)

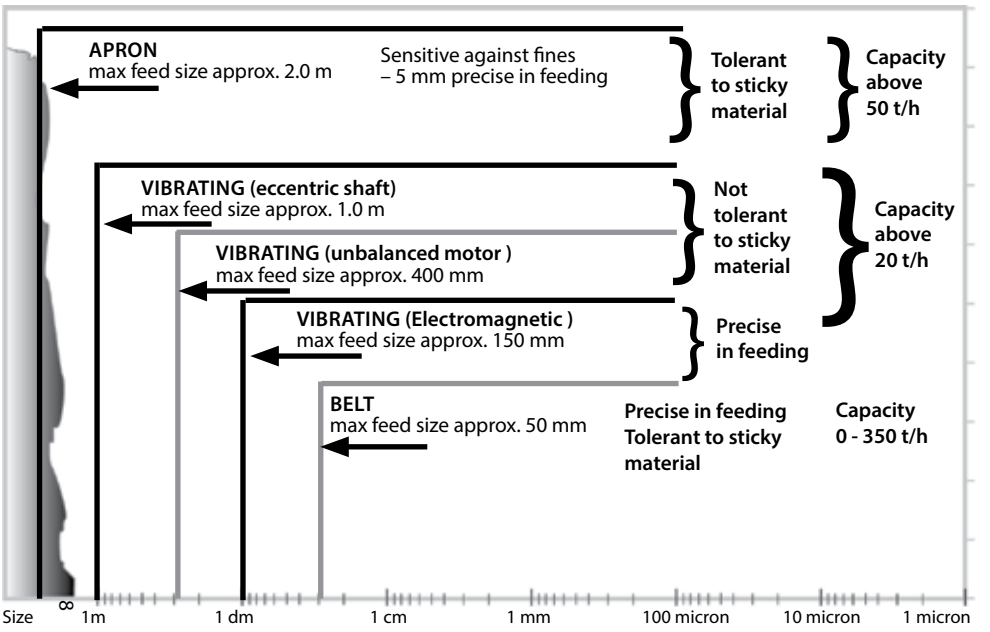


## *Feeding*

Feeders are necessary whenever we want to deliver a uniform flow of dry or moist fractions of rock or minerals.

Generally they are categorized by the size of material to be fed, see below.

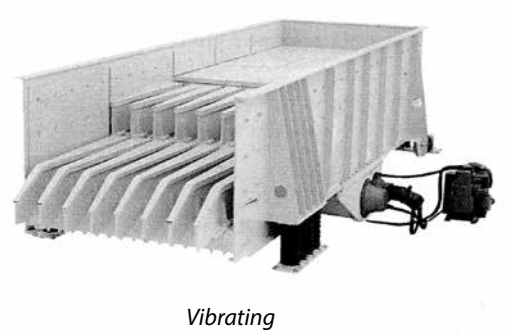
### *Feeding vs Feed sizes*




### *Primary feeders (For installation under feed bumper hoppers & rail car dumpers)*

*Apron*

Capacity 300 – 12 000 t/h

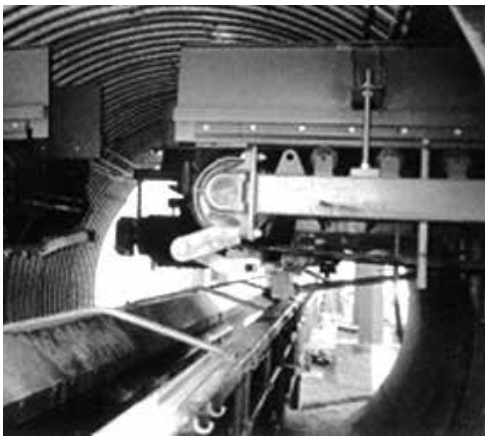


*Vibrating*

Capacity 300 – 1 200 t/h

## *"In circuit" feeders (For installations under ore stockpiles, bins & crusher dischargers)*

*Apron*
Capacity 50 – 3 000 t/h



*Belt*
Capacity 80 – 350 t/h

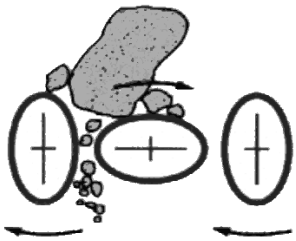
*Vibrating (eccentric shaft)*
Capacity 30 – 600 t/h

*Vibrating (unbalance motor)*
Capacity 55 – 460 t/h

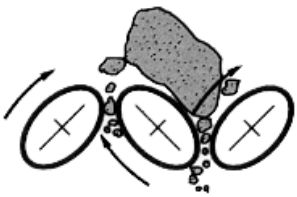
See also data sheets 7:10 - 7:14.

## *Wobbler feeders*

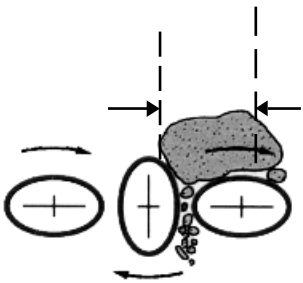
Feeding and scalping - when things get sticky!



Openings between elliptic bars remain constant



Fines, mud or dirt drop through the openings



Oversize moves forward

**Size range**

- See apron and table feeders

**Applications**

- Wet and sticky for:
  metallic, industrial and construction minerals

**Pitch (scalping)**

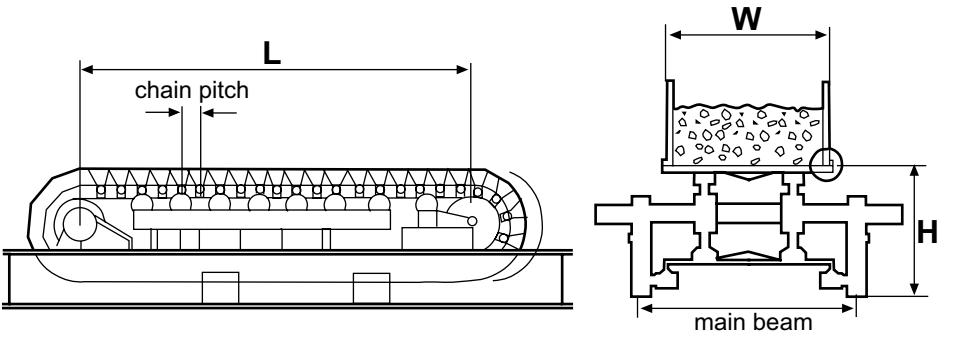
- Fixed and adjustable

**Capacity range**

- Up to 3 500 t/h (5 sizes)

See data sheet 7:15.

# *Feeder – Apron*



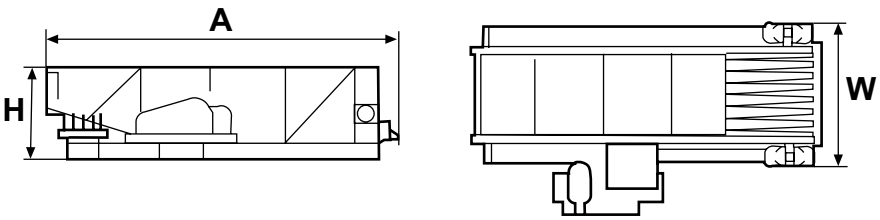

| Model<br>Width (pan)<br>mm/inch | AF 4<br>Weight*<br>ton/lbs | AF 5<br>Weight*<br>ton/lbs | AF 8<br>Weight*<br>ton/lbs | AF 10<br>Weight*<br>ton/lbs | AF 12<br>Weight*<br>ton/lbs | AF 14<br>Weight*<br>ton lbs | AF 16<br>Weight*<br>ton/lbs | AF 18<br>Weight*<br>ton/lbs |
|---|---|---|---|---|---|---|---|---|
| 610/24 | 4.1/9 280 | | | | | | | |
| 762/30 | 4.3/9 734 | 5.1/11 580 | | | | | | |
| 914/36 | 4.6/10 300 | 5.8/1 306 | | | | | | |
| 107/42 | 4.8/10 840 | 6.3/14 020 | | | | | | |
| 1219/48 | 5.6/12 610 | 6.6/14 850 | 8.6/19 160 | | | | | |
| 1372/54 | 6.0/13 430 | 7.1/15 840 | 9.1/20 440 | 11.8/26 470 | | | | |
| 1524/60 | 6.5/14 480 | 7.5/16 770 | 9.9/22 080 | 12.7/28 340 | 17.1/38 360 | | | |
| 1829/72 | 7.6/16 930 | 8.8/19 600 | 11.5/25 870 | 13.9/31 080 | 18.4/41 120 | 22.7/50 800 | | |
| 2134/84 | 8.1/18 070 | 9.8/22 060 | 12.8/28 630 | 16.2/36 260 | 19.8/44 330 | 25.3/56 780 | 51.1/11 4400 | |
| 2438/96 | 8.8/19 650 | 11.4/25 450 | 14.2/31 850 | 17.5/39 120 | 21.1/47 210 | 27.0/60 550 | 56.1/12 5630 | |
| 2743/108 | 9.8/21 860 | 12.5/27 960 | 15.1/33 750 | 18.5/41 480 | 24.3/54 540 | 32.0/71 770 | 62.3/13 9650 | 66.3/14 6220 |
| 3048/120 | 10.7/24 010 | 13.4/29 950 | 16.1/36 100 | 21.3/47 710 | 25.6/57 442 | 32.9/73 730 | 63.9/14 3240 | 65.9/14 7660 |
| 3353/132 | | | | | | 34.6/77 540 | 66.8/14 9730 | 68.7/15 3880 |

*Approx, weight of an Apron feeder, length 3 m (10ft) excl. load, skirts, chutes etc. For each additional feet (or 0.3 m) add 7 % in weight.

Feed size approx, 50% of pan width. Capacity range 50 - 12 000 t/h

| Model | AF 4 | AF 5 | AF 8 | AF 10 | AF 12 | AF 14 | AF 16 | AF 18 |
|---|---|---|---|---|---|---|---|---|
| Chain pitch mm (inch) | 140 (5.5) | 171 (6.8) | 202 (8.0) | 216 (8.5) | 229 (9.0) | 260 (10.3) | 260 (10.3) | 317 (12.5) |
| Main beam width mm (inch) | Width pan +356 (14) | Width pan +457 (18) | Width pan +457 (18) | Width pan +457 (18) | Width pan +508 (20) | Width pan +584 (23) | Width pan +584 (23) | Width pan +610 (24) |
| Feeder length | suitable | suitable | suitable | suitable | suitable | suitable | suitable | suitable |
| Height (H) mm (inch) | 889 (35) | 1 041 (41) | 1 268 (50) | 1 372 (54) | 1 625 (64) | 1 753 (69) | 1 803 (71) | on site demands |

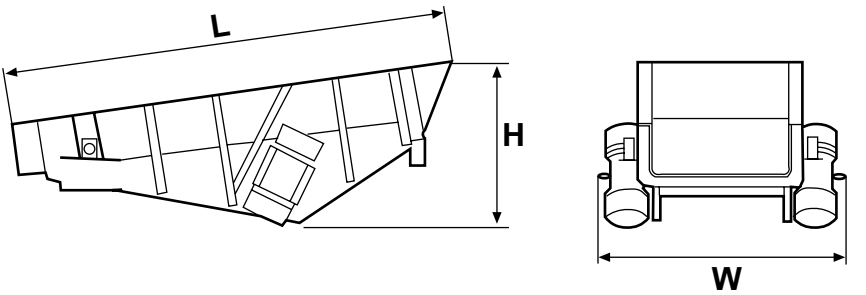
## *Feeder – Vibration (linear motion)*




| Model (VMHC)* | H mm (inch) | L mm (inch) | W mm (inch) | Weight ton | Capacity ton/h | Max. size mm (inch) |
|---|---|---|---|---|---|---|
| 48/12 | 1 300 (51) | 5 200 (205) | 2 050 (81) | 6.8 | 280 - 400 | 650 (26) |
| 48/15 | 1 300 (51) | 5 160 (203) | 2 350 (93) | 10.0 | 420 - 600 | 850 (33) |
| 60/10 | 1 870 (74) | 6 800 (268) | 1 860 (73) | 13.2 | 250 - 350 | 500 (20) |
| 60/12 | 1 870 (74) | 6 800 (268) | 2 060 (81) | 14.0 | 280 - 400 | 650 (26) |
| 60/15 | 1 950 (77) | 6 800 (268) | 2 380 (94) | 15.0 | 420 - 600 | 850 (33) |
| 60/18 | 1 650 (65) | 6 550 (258) | 2 680 (106) | 16.5 | 550 - 800 | 1 000 (39) |
| 72/21 | 2 250 (89) | 7 800 (307) | 2 980 (117) | 21.5 | 700 - 1200 | 1 000 (39) |

* One, two or three grizzly sections as option depending on size

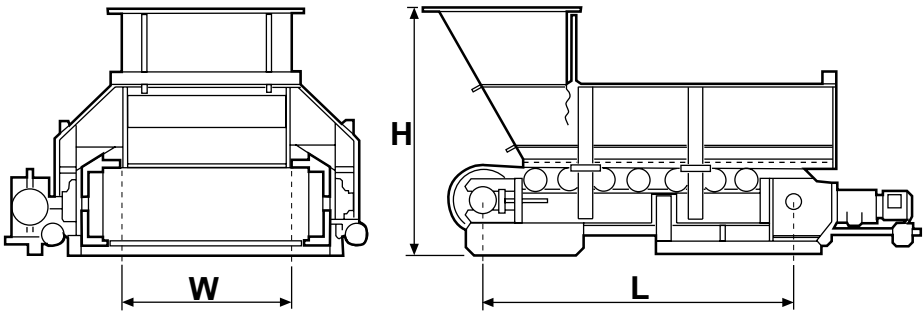
## *Feeders – Unbalanced motor*




| Model (VMO) | H mm (inch) | L mm (inch) | W mm/inch | Weight ton | Capacity* ton/h* |
|---|---|---|---|---|---|
| 15/6.5 - 3014 | 780 (31) | 1 770 (70) | 1 260/50 | 0.5 | 30 – 160 |
| 17.5/8 - 40 | 830 (33) | 2 050 (81) | 1 410/56 | 0.7 | 40 – 210 |
| 20/10 - 40 | 950 (37) | 2 300 (91) | 1 670/66 | 1.1 | 60 – 320 |
| 30/10 - 40 | 1 000 (39) | 3 300 (130) | 1 670/66 | 1.5 | 60 – 300 |
| 30/10 - 45 | 1 000 (39) | 3 300 (130) | 1 720/68 | 1.7 | 100 – 500 |
| 20/12.5 - 45 | 950 (37) | 2 300 (91) | 1 030/41 | 1.3 | 90 – 550 |
| 25/12.5 - 45 | 1 050 (41) | 2 790 (110) | 1 970/76 | 1.8 | 90 – 550 |

* Capacity at 8° inclination. feed moist sand 1-7mm (16-3 mesh)

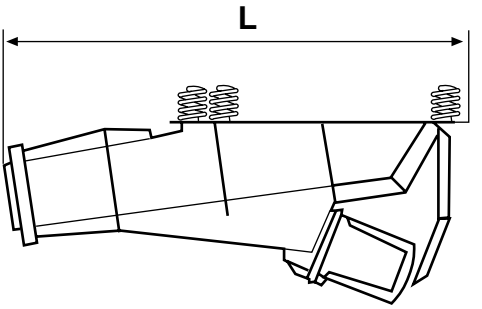
## *Feeder – Belt*

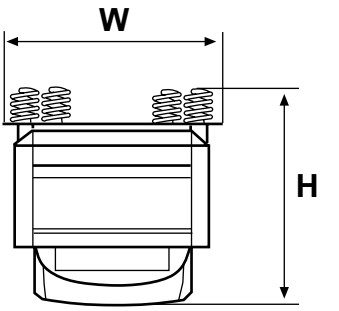



| Model (VMO) | H mm (inch) | L mm (inch) | W mm/inch | Weight ton | Capacity* ton/h* |
|---|---|---|---|---|---|
| 10/4.5 | 1 050 (41) | 1 000 (39) | 450 (18) | 0.64 | 180 |
| 15/4.5 | 1 050 (41) | 1 500 (59) | 450 (18) | 0.71 | 180 |
| 20/4.5 | 1 050 (41) | 2 000 (78) | 450 (18) | 0.80 | 180 |
| 10/6 | 1 200 (47) | 1 000 (39) | 600 (24) | 0.77 | 250 |
| 15/6 | 1 200 (47) | 1 500 (59) | 600 (24) | 0.89 | 250 |
| 20/6 | 1 200 (47) | 2 000 (78) | 600 (24) | 0.94 | 250 |
| 10/8 | 1 200 (47) | 1 000 (39) | 800 (31) | 0.98 | 350 |
| 15/8 | 1 200 (47( | 1 500 (59) | 800 (31) | 1.10 | 350 |
| 20/8 | 1 200 (47) | 2 000 (78) | 800 (31) | 1.20 | 350 |

* Max feed size 50 mm (2″)

## *Feeder – Electromagnetic*



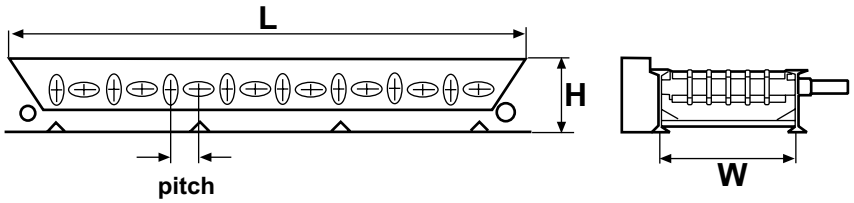






| Model (VMm) | H mm (inch) | L mm (inch) | W mm/inch | Weight ton | Capacity* ton/h* |
|---|---|---|---|---|---|
| 6/4-8D | 455 (18) | 825 (32) | 510 (20) | 60 (130) | 55 |
| 11/4-20D | 570 (23) | 1 260 (50) | 540 (20) | 115 (255) | 60 |
| 8/5.6-20D | 650 (26) | 1 120 (44) | 660 (27) | 120 (265) | 110 |
| 8/5.6 50D | 765 (30) | 1 120 (44) | 660 (27) | 195 (425) | 150 |
| 14/5.6 50D | 765 (30) | 1 630 (64) | 780 (30) | 280 (615) | 140 |
| 12/8-50D | 835 (33) | 1 580 (60) | 950 (37) | 330 (730) | 230 |
| 12/8-100D | 1 060 (42) | 1 600 (63) | 950 (37) | 440 (975) | 270 |
| 18/8-100D | 1 060 (42) | 2 175 (86) | 970 (38) | 560 (1235) | 270 |
| 18/8-2x100D | 1 430 (56) | 2 170 (85) | 970 (38) | 795 (1750) | 310 |
| 14/10-100D | 1 105 (44) | 1 960 (77) | 1 210 (48) | 580 (1280) | 410 |
| 14/10-2x100D | 1 485 (58) | 1 960 (77) | 1 180 (46) | 815 (1795) | 460 |
| 22/10-2x100D | 1 485 (58) | 2 710 (106) | 1 210 (48) | 1 170 (2580) | 390 |
| 18/12.5-2x100D | 1 430 (56) | 2 395 (94) | 1 435 (56) | 1 150 (2535) | 460 |

* Capacity calculated at bulk weight 1600 kg/m$^3$ (100 $^3$lb/ft) and size of feed 16-25mm (0.75-1″), inclination 8°, feeder encapsulated. (Non-encapsulated will increase capacity 10%)

## *Feeder – Wobbler*




| Pitch 175 (7″) Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight ton | Power kW/hp |
|---|---|---|---|---|---|
| 609 (24)–14* | 429 (17) | 2 829 (111) | 727 (29) | 2.0 | 5.6/7.5 |
| 914 (36)–14* | 429 (17) | 2 829 (111) | 1 032 (41) | 2.3 | 7.5/10.0 |
| 1219 (48)-18 | 429 (17) | 3 527 (139) | 1 337 (53) | 3.1 | 7.5/10.0 |
| 1372 (54)-18 | 429 (17) | 3 527 (139) | 1 489 (59) | | 7.5/10.0 |
| * also with 16 and 18 bars | same | add 349 (14) for each double bar | same | add 10% for each double bar | same |

* **609(24) –14,** 609 (24) = width of wobble bars – 14 number of bars.

Max feed size 406 mm (16″)

| Pitch 229 (9″) Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight ton | Power kW/hp |
|---|---|---|---|---|---|
| 914 (36)-16* | 648 (26) | 4 178 (165) | 1 105 (44) | 5 4 | 11/15 |
| 1219 (48)-16* | 648 (26) | 4 178 (165) | 1 410 (56) | 6 0 | 11/15 |
| 1372 (54)-16* | 648 (26) | 4 178 (165) | 1 562 (62) | 6 7 | 15/20 |
| 1524 (60)-16* | 648 (26) | 4 178 (165) | 1 715 (68) | 7 7 | 15/20 |
| 1829 (72)-16* | 648 (26) | 4 178 (165) | 2 019 (80) | 8 3 | 15/20 |
| * also with18. 20 and 22 bars | same | add 457 (18) for each double bar | same | add 10% for each double bar | same |

Max feed size 762 mm (30″)

| Pitch 292 (11.5″) Model | H mm (inch) | L mm (inch) | W mm (inch) | Weight ton | Power kW/hp |
|---|---|---|---|---|---|
| 914 (36)-16* | 648 (26) | 5 131 (202) | 1 105 (44) | 6.6 | 15/20 |
| 1219 (48)-16* | 648 (26) | 5 131 (202) | 1 410 (56) | 8.1 | 15/20 |
| 1372 (54)-16* | 648 (26) | 5 131 (202) | 1 562 (62) | 8.4 | 15/20 |
| 1524 (60)-16* | 648 (26) | 5 105 (201) | 1 715 (68) | 8.6 | 15/20 |
| 1829 (72)-16* | 648 (26) | 5 105 (201) | 2 019 (80) | 9.2 | 15/20 |
| * also with18. 20 and 22 bars | same | add 584 (23) for each double bar | same | add 10% for each double bar | same |

Max feed size 762 mm (30″)

**Wobbler feeder also available with 318 mm (12.5″) pitch and 368 mm (14.5″) pitch for feed size up to 1900 mm (75″).**

# *Conveying*

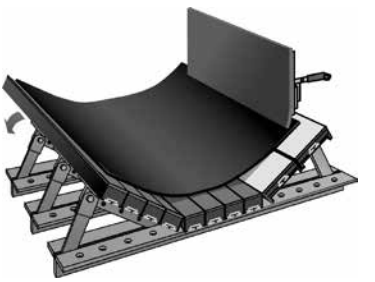
In this section we will focus on mineral mass flow by conveying, by far the dominating method when transporting dry material in a mineral processing operation.

## *Conveyor – general*

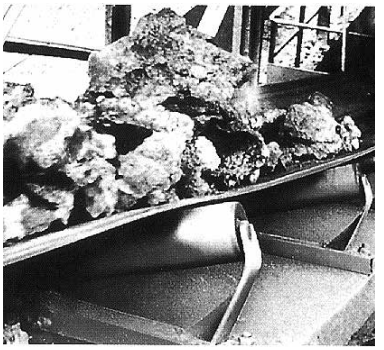
Conveyors are selected from 4 key parameters:

- Tonnage
- Material and size
- Inclination
- Distance

We also must consider wear in operation and the environment (dust, heat, oil or chemicals etc)



*Wear Part*



*Tonnage and size*

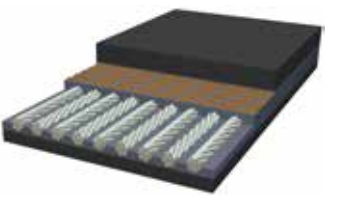
*Distance*

*Inclination*



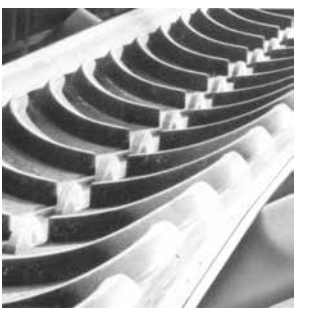
## *Conveyor belts*

Although the conveyor structure is important, most of the conveying work falls back on the conveyor belt, exposed to the material.
**Flat belts** are dominating, conveying up to a lifting or lowering angle of approx. 18°. Depending on duty the belts are reinforced with different materials (Polyester/ Polyamide, Aramid and Steel Cords) , protected by top and bottom covers.
The polymer material in the belt (mainly rubber) is selected according to appearance of heavy wear, heat, flames, oil etc.



**Profile belts** must be used when lifting angle is exceeding 18° . With a limitation of approx. 30° different profiles of the top cover must be selected to prevent bulk material or unit loads from sliding backward. Otherwise reinforcement and material selection criteria are similar as for flat belts above.

See data sheet 7:20

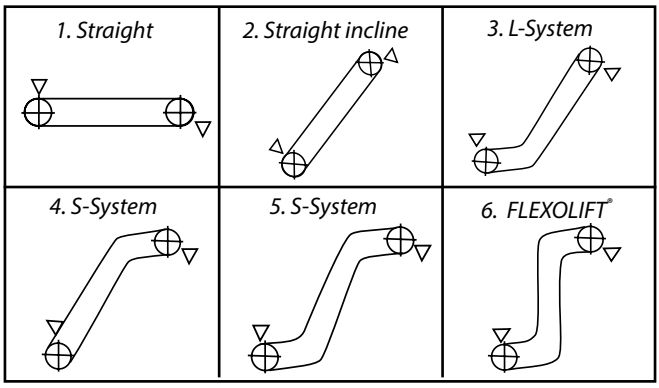


# Conveying systems

## Vertical conveyor system "When space is critical"

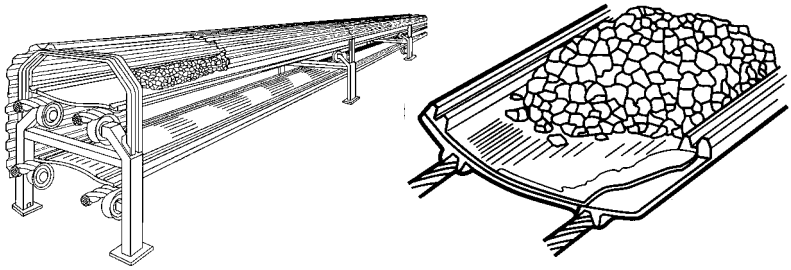
Vertical conveying systems normally is the only option when lifting angle is exceeding 30°. The system is very flexible and gives a number of transportation solutions when space and lifting angles are critical.

See data sheet 7:21




## Cable Belt® conveyor system "When distance is critical"

Conveying with high capacities over long distances means that conventional conveying systems are out. An alternative to truck hauling is Cable Belt® conveyors which become competitive from, say, 500 m and upwards taking on capacities from 500 up to 5000t/h.

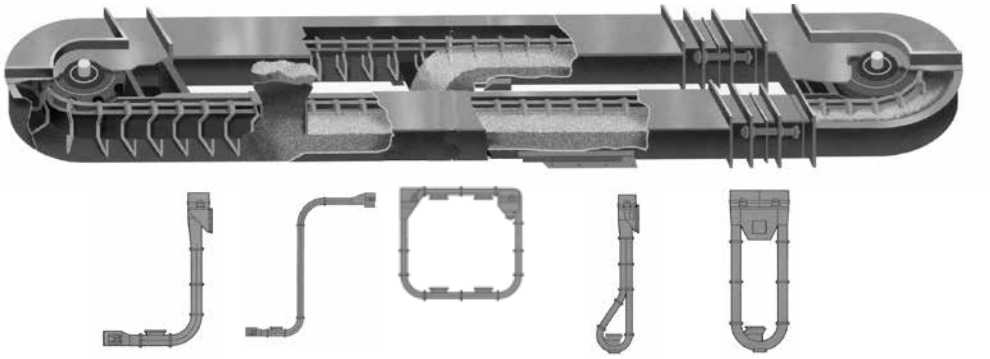


See also 7:21

## En-masse conveying system "When dust and emissions are critical"

Transportation of free-flowing bulk material with or without gas emissions or high temperatures places special demands on the conveyor system. En-Masse conveying system is aiming at gentle handling and a closed material flow system for transportation in all directions. Material moves in a solid placid column along with the conveying chain equipped with different types of conveying flights depending on duty.

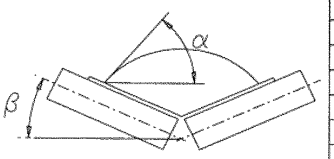
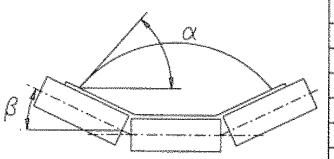
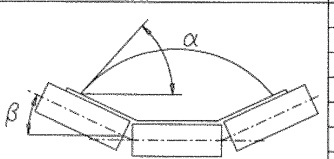
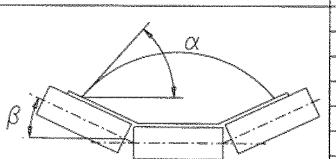
*Configurations*



## Conveyor capacities

In order to estimate the capacity and max. recommended inclination of a conventional conveyor the figures below can be of use.

**Conveyor capacity in m³ per hour by belt speed 1 m/sec**

| Angle of idler sets ß | | Material-angle α | Belt width 500 | 650 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|---|---|
| 25° |  | 0° | 61 | - | - | - | - |
| | | 5° | 72 | - | - | - | - |
| | | 10° | 84 | - | - | - | - |
| | | 15° | 96 | - | - | - | - |
| | | 20° | 108 | - | - | - | - |
| | | 25° | 122 | - | - | - | - |
| | | 30° | 136 | - | - | - | - |
| 15° |  | 0° | - | 60 | 95 | 162 | 239 |
| | | 5° | - | 85 | 134 | 226 | 334 |
| | | 10° | - | 110 | 173 | 291 | 430 |
| | | 15° | - | 136 | 213 | 358 | 530 |
| | | 20° | - | 163 | 256 | 428 | 634 |
| | | 25° | - | 192 | 300 | 503 | 745 |
| | | 30° | - | 223 | 350 | 585 | 865 |
| 25° |  | 0° | - | 96 | 151 | 256 | 378 |
| | | 5° | - | 119 | 187 | 316 | 466 |
| | | 10° | - | 142 | 224 | 376 | 555 |
| | | 15° | - | 166 | 261 | 439 | 647 |
| | | 20° | - | 192 | 300 | 504 | 743 |
| | | 25° | - | 218 | 343 | 574 | 846 |
| | | 30° | - | 248 | 388 | 649 | 957 |
| 30° |  | 0° | - | 112 | 175 | 300 | 442 |
| | | 5° | - | 134 | 209 | 356 | 526 |
| | | 10° | - | 156 | 244 | 413 | 610 |
| | | 15° | - | 179 | 280 | 472 | 698 |
| | | 20° | - | 203 | 318 | 535 | 790 |
| | | 25° | - | 229 | 358 | 600 | 887 |
| | | 30° | - | 257 | 400 | 673 | 993 |

## Volume weight and angle of inclination

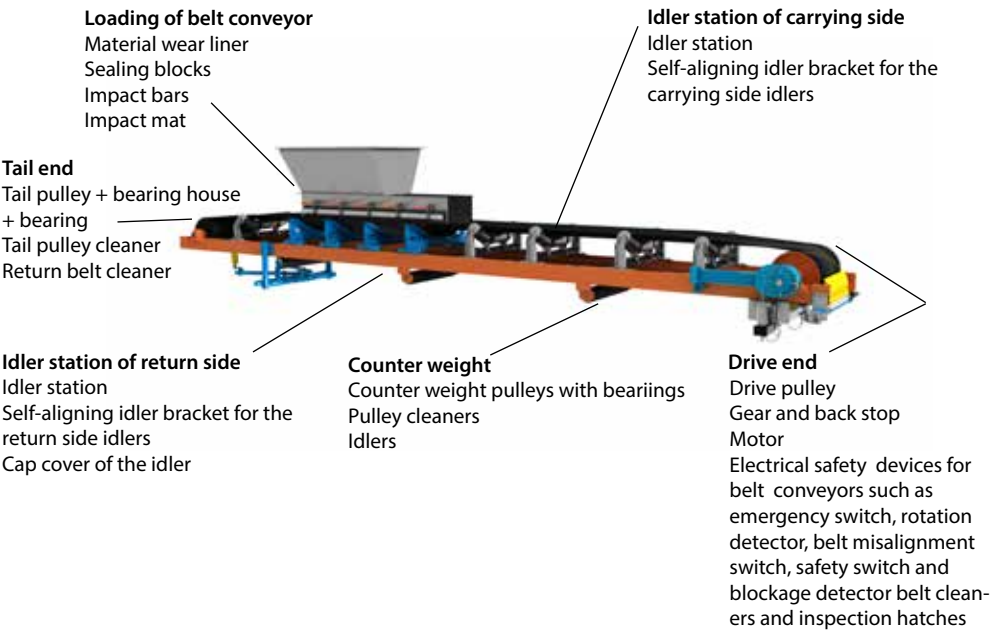
The capacity and the inclination of the conveyors depend on the character of the material to be conveyed.

| Material | Volume weight in tons/cbm. | Max. inclination in degrees |
|---|---|---|
| Bauxit, crushed | 1.3 | 18 |
| Briquettes, normal | 0.7-0.82 | 15-18 |
| Briquettes, oviform | 0.7-0.82 | 12-13 |
| Cement | 1.2-1.6 | 20-22 |
| Cement clinkers | 1.2-1.3 | 18 |
| Chalk, crushed | 1.2-1.4 | 18 |
| Charcoal | 0.2-0.25 | 18 |
| Clay, lumps, moist | 1.5-1.7 | 18 |
| Clinkers | 1.2-1.5 | 18 |
| Coal, bituminous, fine | 0.67-0.75 | 15-20 |
| Coal, bituminous, moist | 0.67-0.75 | 18-20 |
| Coal, pit coal | 0.7-0.8 | 18-20 |
| Coke | 0.4-0.67 | 18-20 |
| Concrete, moist | 1.6-2.2 | 24-27 |
| Dolomit stone | 1.4-1.6 | 18 |
| Earth, dry | 1.2-1.3 | 20 |
| Earth, moist | 1.5-1.7 | 23 |
| Fertilizers | 0.9-1.2 | 20 |
| Granite, broken | 1.5-1.6 | 18 |
| Gravel, dry | 1.45-1.55 | 15 |
| Gravel, moist | 1.6-1.75 | 18 |
| Gypsum, lumps | 1.4-1.6 | 18 |
| Gypsym, powder | 0.95-1.05 | 23 |
| Iron ore, dry | 2.5 | 18-20 |
| Iron ore, moist | 3.5 | 20-22 |
| Iron ore, primary crushed | 2.0-3.0 | 18 |
| Iron ore, secondary crushed | 2.4-3.5 | 22 |
| Kaolin | 1.0 | 19 |
| Lime, lumps | 1.05-1.15 | 23 |
| Lime, powder | 1.0-1.2 | 21-23 |
| Limestone, crushed | 1.3-1.5 | 18 |
| Manganese ore | 2.0-2.25 | 18 |
| Marble, crushed | 1.5-1.6 | 18 |
| Peat | 0.4-0.6 | 16 |
| Potash | 1.1-1.6 | 18 |
| Pyrites, crushed | 2.2 | 20 |
| Rubble | 1.7-2.1 | 20-22 |
| Salt, fine | 1.1-1.3 | 15 |
| Salt, rock salt | 1.0-1.2 | 18-24 |
| Sand, dry | 1.5 | 15 |
| Sand, moist | 2.0 | 22 |
| Sinter | 1.4 | 12 |
| Sinter, coal sinter | 3.5 | - |
| Slag, coarse | 0.75-0.9 | 18 |
| Slate, crushed | 1.2-1.35 | 18-20 |
| Soot | 0.4-0.8 | - |
| Splinters | 0.2-0.48 | 22-24 |
| Stone, crushed | 1.5-1.6 | 18 |

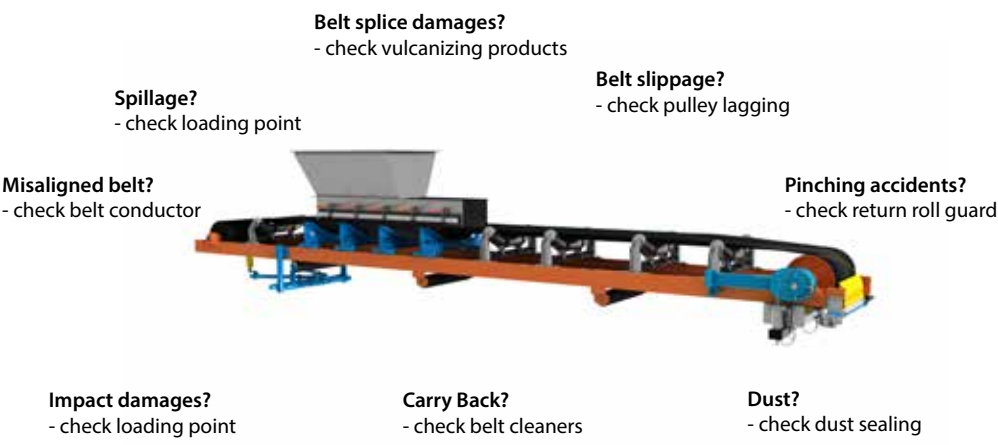
## *Conveyor – More than a rubber belt*

The conveyors are the working horses of every dry processing plant in mineral processing, of key importance to keep the process flow stable.

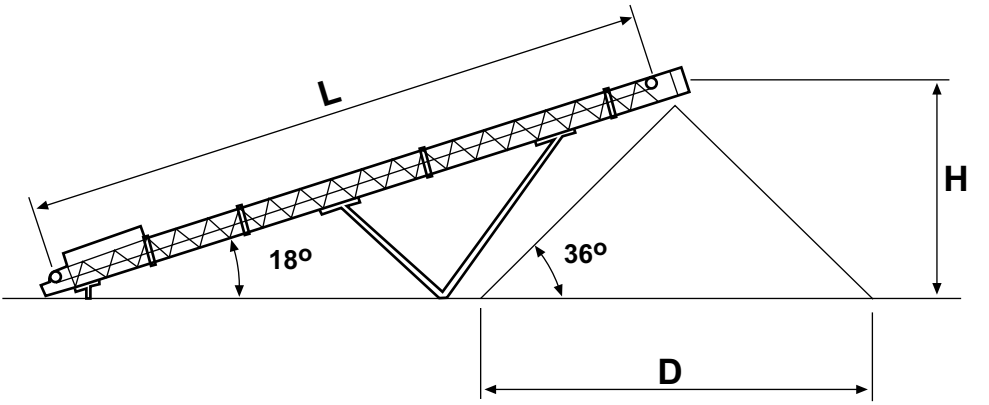
Pictures below indicate the vital parts of the conveyor and the critical service points to be checked regularly for reliable operation.


**Loading of belt conveyor**
Material wear liner
Sealing blocks
Impact bars
Impact mat
**Idler station of carrying side**
Idler station
Self-aligning idler bracket for the carrying side idlers
**Tail end**
Tail pulley + bearing house + bearing
Tail pulley cleaner
Return belt cleaner
**Idler station of return side**
Idler station
Self-aligning idler bracket for the return side idlers
Cap cover of the idler
**Counter weight**
Counter weight pulleys with beariings
Pulley cleaners
Idlers
**Drive end**
Drive pulley
Gear and back stop
Motor
Electrical safety devices for belt conveyors such as emergency switch, rotation detector, belt misalignment switch, safety switch and blockage detector belt cleaners and inspection hatches

### *Conveyor – service points*



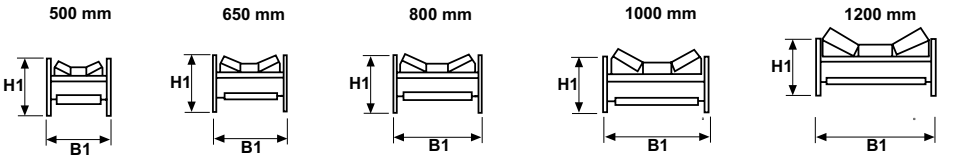
## *Conveyor – Standard belt*




| L m (ft) | | H m (ft) | | D mm (ft) | | Volume $m^3$ ($ft^3$) | |
|---|---|---|---|---|---|---|---|
| 6 | (20) | 2.4 | (7.8) | 6.5 | (21.3) | 26 | (918) |
| 7 | (23) | 2.7 | (8.9) | 7.3 | (24.0) | 38 | (1 342) |
| 8 | (26) | 3.0 | (9.8) | 8.2 | (26.9) | 53 | (1 872) |
| 9 | (30) | 3.3 | (10.8) | 9.0 | (30.0) | 71 | (2 507) |
| 10 | (33) | 3.6 | (11.8) | 9.9 | (32.5) | 93 | (3 284) |
| 12 | (40) | 4.2 | (13.8) | 11.6 | (38.1) | 149 | (5 263) |
| 14 | (46) | 4.8 | (15.7) | 13.3 | (43.6) | 225 | (7 946) |
| 16 | (52) | 5.4 | (17.7) | 15.0 | (49.2) | 323 | (11 407) |
| 18 | (60) | 6.1 | (20.0) | 16.7 | (54.8) | 446 | (15 750) |
| 20 | (66) | 6.7 | (22.0) | 18.4 | (60.4) | 596 | (21 048) |
| 22 | (72) | 7.3 | (24.0) | 20.1 | (65.9) | 777 | (27 440) |
| 24 | (80) | 7.9 | (26.0) | 21.8 | (71.5) | 992 | (35 032) |
| 26 | (85) | 8.5 | (28.0) | 23.5 | (77.1) | 1 243 | (43 896) |
| 28 | (92) | 9.2 | (30.2) | 25.2 | (82.7) | 1 533 | (54 137) |
| 30 | (49) | 9.8 | (32.2) | 26.9 | (88.3) | 1 865 | (65 862) |
| 35 | (115) | 10.8 | (35.4) | 31.1 | (102.0) | 2 861 | (101 135) |
| 40 | (132) | 12.9 | (42.3) | 35.4 | (116.1) | 4 232 | (149 452) |
| 45 | (148) | 14.4 | (47.2) | 39.7 | (130.2) | 5 942 | (209 840) |
| 50 | (164) | 16.0 | (52.0) | 44.0 | (144.0) | 8 109 | (286 367) |

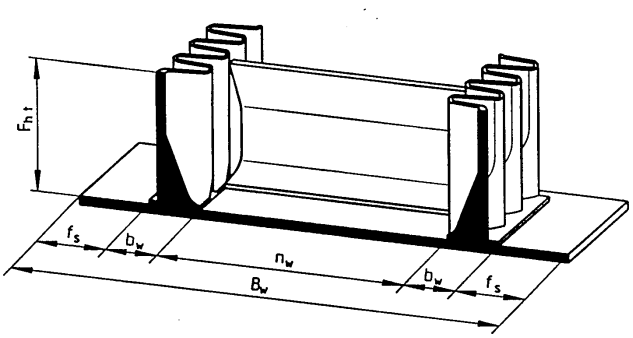
**Frame height (H1) – width (B1)**

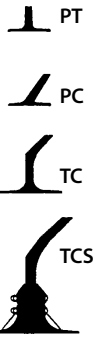
| Lenght (belt) m/ft | Belt width 500 mm/20 in H1 - B1 mm/in | Belt width 650 mm/26 in H1 – B1 mm/in | Belt width 800 mm/32 in H1 – B1 mm/in | Belt width 1000 mm/40in H1 – B1 mm/in | Belt width 1200 mm/47 in H1 – B1/mm/in |
|---|---|---|---|---|---|
| 6-14/20-46 | 800/32-890/35 | 800/32-1040/41 | 800/32-1240/49 | 800/32-1440/57 | 800/32-1690/67 |
| 15-24/49-79 | 800/32-890/35 | 800/32-1040/41 | 800/32-1240/49 | 800/32-1440/57 | 800/32-1690/67 |
| 25-30/82-98 | 1210/48-950/37 | 1210/48-1100/43 | 1210/48-1300/51 | 1210/48-1500/59 | 1210/48-1750/69 |
| 30-50/82-164 | 1210/48-950/37 | 1210/48-1100/43 | 1210/48-1300/51 | 1210/48-1500/59 | 1210/48-1750/69 |



## *Vertical conveyor system*

The vertical conveyer systems for material transportation is an engineered system with many variations.
Below you will find some basic data covering the belt, the sidewalls and the cleats to be considered.




**Belt width: (Bw)** depending on net width (see below)

**Free lateral space: (fs)** depending on belt deflection discs

**Net belt width: (nw)** depending on material size, see below

**Sidewall height: (Fht)** depending on material size, see below

**Sidewall width: (bw)** depending on sidewall height above

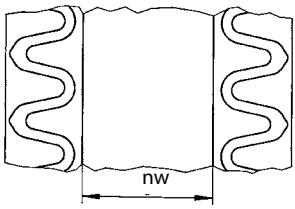
**Cleat type:** depending on duty, see below

**Cleat height: (Ch)** depending on material size, see below

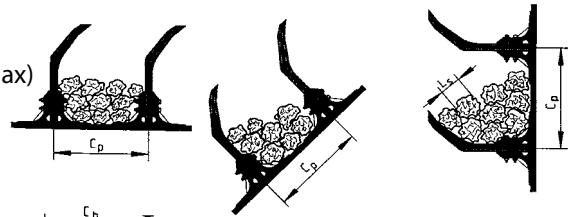
**Cleat pitch: (Cp)** depending on material size, see below

**Material (Lump) size: (Ls)**

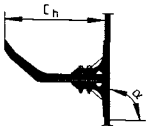
**Net belt width: nw** (min) ~ 2,1x**Ls** (max.)




**Cleat pitch**: **Cp** (min) ~1,5x**Ls** (max)




**Cleat height: Ch** (min) ~ **Ls** ($\alpha$/100+0.5)



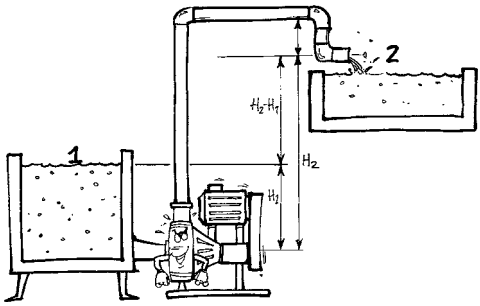

**Cleat types: PT** height 20 – 110 mm (0,8 – 4,3 inch), **PC** height 35 – 180 mm (1,4 –7,1 inch) **TC** height 110 –160 mm (4,3 – 10,2 inch), **TCS** height 400 – 500 mm (16 – 20 inch)

Sidewall heights **Fht** from 40mm (1,6 inch) to 630 mm (25 inch)

# *Slurry Handling – Introduction*

## *Hydraulic transportation of solids*

In all wet industrial processes "hydraulic transportation of solids" is a technology, moving the process forward between the different stages of Liquid / Liquid mixing, Solid / Solid separation, Liquid / Liquid separation, etc.

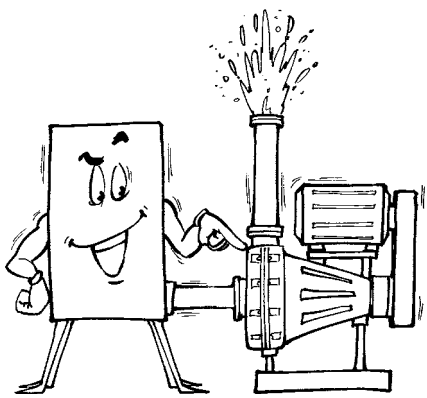



## *What type of solids?*

Solids can be almost anything that is

Hard • Coarse • Heavy • Abrasive • Crystalline • Sharp • Sticky • Flaky • Long • Fibrous • Frothy

*You name it - it can be transported hydraulically !*



## *What type of liquids?*

In most applications the liquid is only the "carrier". In **98% of the industrial applications the liquid is water.**

Other types of liquids may be chemical solutions like acids and caustics, alcohol, light petroleum liquids (kerosene), etc.

## *Definition of a slurry*

The mixture of solids and liquids is normally referred to as a "slurry" or "pulp"!

A slurry can be described as a two phase medium (liquid/solid).

Slurry mixed with air (common in many chemical processes) is described as a three phase fluid medium (liquid/solid/gas).

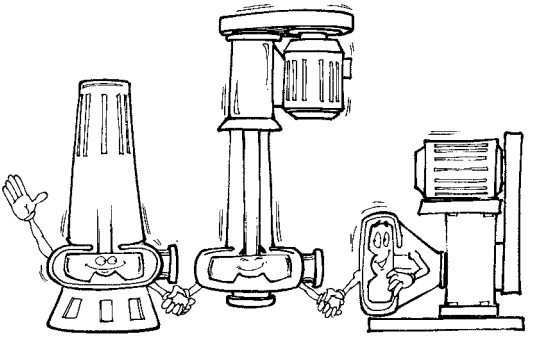
## What are the limitations in flow?

In theory there are no limits to what can be hydraulically transported. Just look at the performance of hydraulic transportation of solids in connection with the glaciers and the big rivers!

In practice the limitations in **flow** for a slurry pump installation are from **1 m$^3$/hour (4 GPM)** up to **20 000 m$^3$/hour (88 000 GPM)**

The lower limit is determined by the efficiency drop for smaller pumps.

The higher limit is determined by the dramatic increase of costs for large slurry pumps (compared to multiple pump installations).

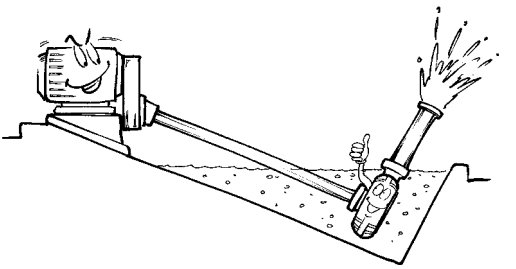


## What are the limitations for solids?

The limitation for the solids is the geometrical shape and size and the risk of blocking the passage through a slurry pump.

The maximum practical **size** of material to be mass transported in a slurry pump is approximately **50 mm (2 inch).**

However, individual lumps of material passing through a large dredge pump can be up to **350 mm (14 inch)** (depending of the dimensioning of the wet end).



## Slurry pumps as an operation concept

Of all centrifugal pumps installed in the process industry the ratio between slurry pumps and other pumps for liquid is 5:**95**

If we look at the operating costs for these pumps the ratio is nearly the opposite **80**:**20**

This gives a very special profile to slurry pumping and the market concept has been formulated as follows:

*"Install a pump on clean liquid and forget about it"!*

*"Install a pump on slurry and you have a service potential for the rest of its life"!*

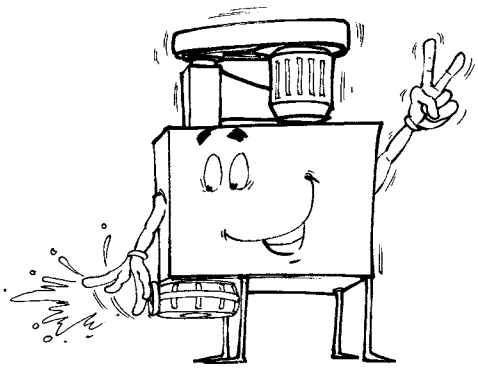
This is valid both for the end user and the supplier.

# Basic definitions

## Why slurry pumps?

By definition slurry pumps are heavy and robust versions of centrifugal pumps, capable in handling tough and abrasive duties.

"A slurry pump should also be considered as a generic term, to distinguish it from other centrifugal pumps mainly intended for clear liquids".



## Slurry pump – name by duty

The term slurry pump, covers various types of heavy duty centrifugal pumps used for hydraulic transportation of solids.

A more precise terminology is to use the classification of solids handled in the various pump applications.

**Slurry pumps** cover pumping of mud/clay, silt and sand in the size range of solids up to 2 mm (9 mesh)

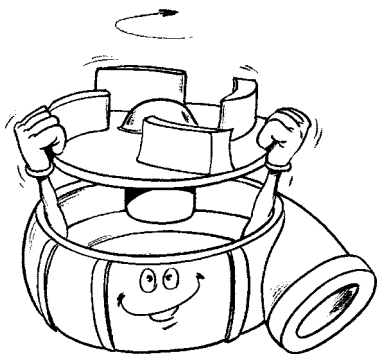
**Size ranges are:**

| | |
|---|---|
| Mud/clay: | minus 2 microns |
| Silt: | 2 – 50 microns |
| Sand, fine: | 50 – 100 microns (270 – 150 mesh) |
| Sand, medium: | 100 – 500 microns (150 – 32 mesh) |
| Sand, coarse: | 500 – 2 000 microns (32 – 9 mesh) |

**Sand & gravel pumps** cover pumping of shingle and gravel in the 2 – 8 mm (9 – 2,5 mesh) size range

**Gravel pumps** cover pumping of solid sizes up to 50 mm (2 inch).

**Dredge pumps** cover pumping of solid sizes up to and above 50 mm (2 inch).



## *Slurry pump – name by application*

Process applications also provide the terminology, typically

**Froth pumps** define by application the handling of frothy slurries, mainly in flotation.

**Carbon transfer pumps** define the gentle hydraulic transportation of carbon in CIP (carbon in pulp) and CIL (carbon in leach) circuits.

**Sump pumps,** also an established name typically operating pumps from floor sumps, submerged pump houses, but having dry bearings and drives.

**Submersible pumps,** the entire unit, including drive, is submersed.

## *All slurry pumps are in practice named after the given application:*

- Slurry pumps • Gravel pumps • Dredge pumps • Sump pumps • Froth pumps
- Carbon Transfer pumps • Submersible pumps

## *There are principally three different designs:*

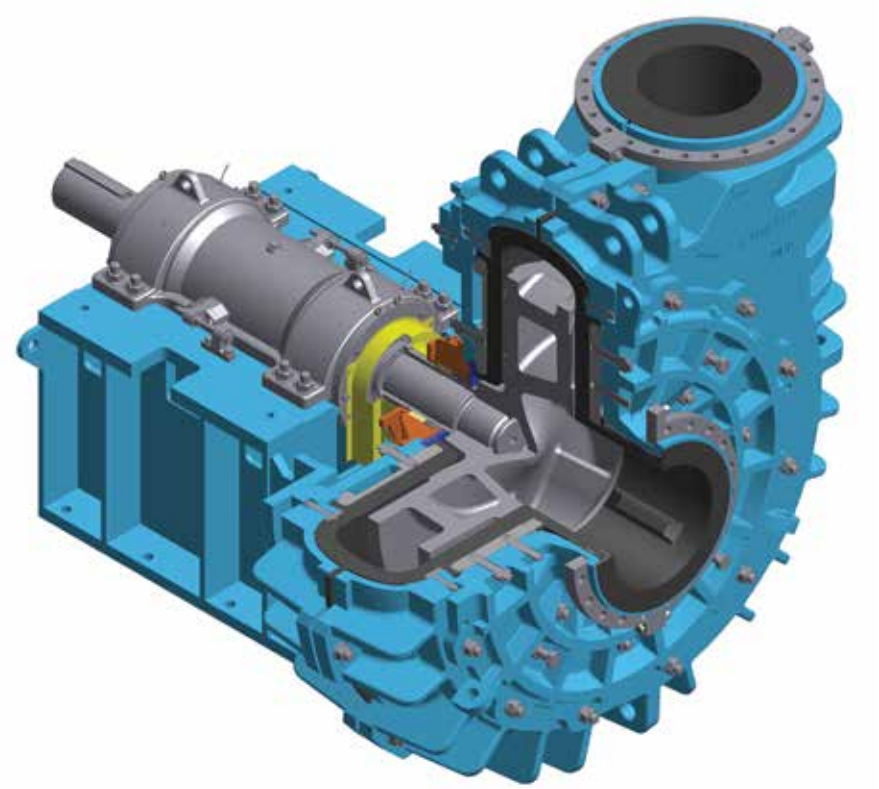
- Horizontal and vertical tank (dry installation) • Vertical sump (semi dry installation)
- Tank (dry installation) • Submersible (wet installation)

## *Slurry pump designs are selected and supplied according to the wear conditions*

- Highly abrasive • Abrasive • Mildly abrasive

# Slurry pump range MD

## The Metso series hard metal and rubber lined mill discharge pumps





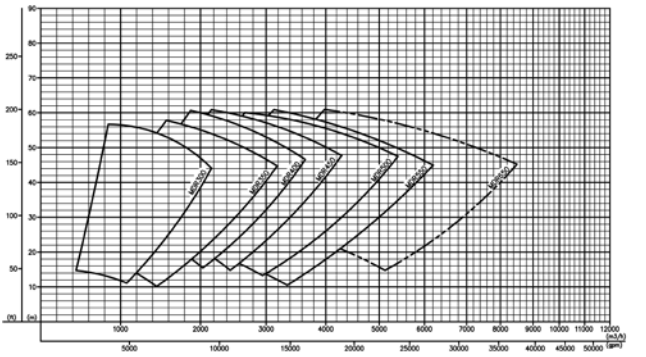
### Summary of design features

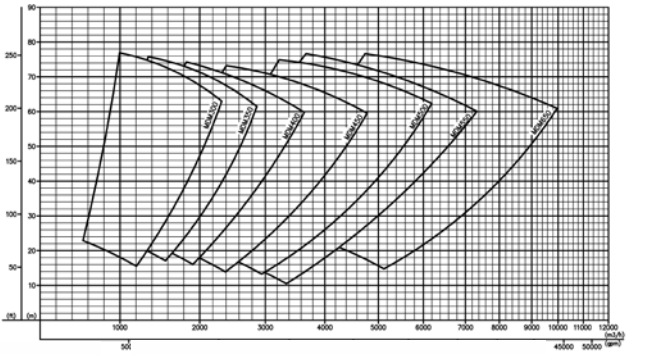
- High sustained efficiency
- Even hydraulic wear
- Longer operating life
- Oversized robust steel shaft
- Extra thick casings and liners at known points of wear
- Back pull-out option for ease of maintenance
- Self contained oil or grease lubricated bearing cartridge assembly with non contact labyrinth seals for maintenance free operation
- Bearing housing arranged to accept temperature and vibration sensors
- Split stuffing box gland and gland guard
- Various shaft seal options including Metso EnviroSet™
- Modular design with good interchangeability of parts
- Loose steel flange connections

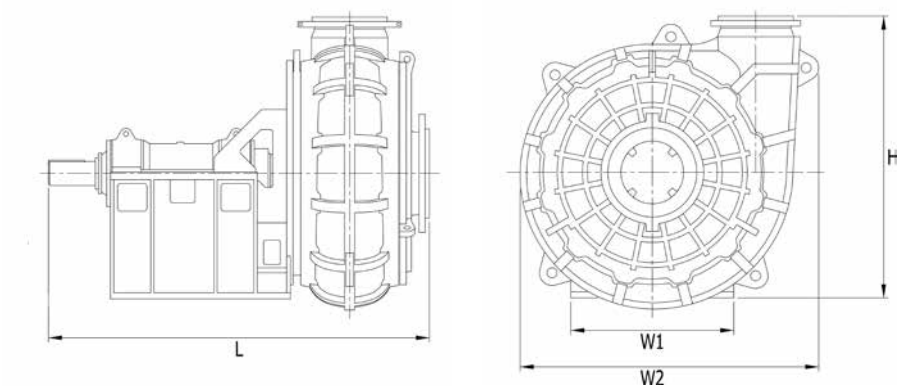
See data sheets on next page.

# *Slurry pump range MD*

## *Selection charts*







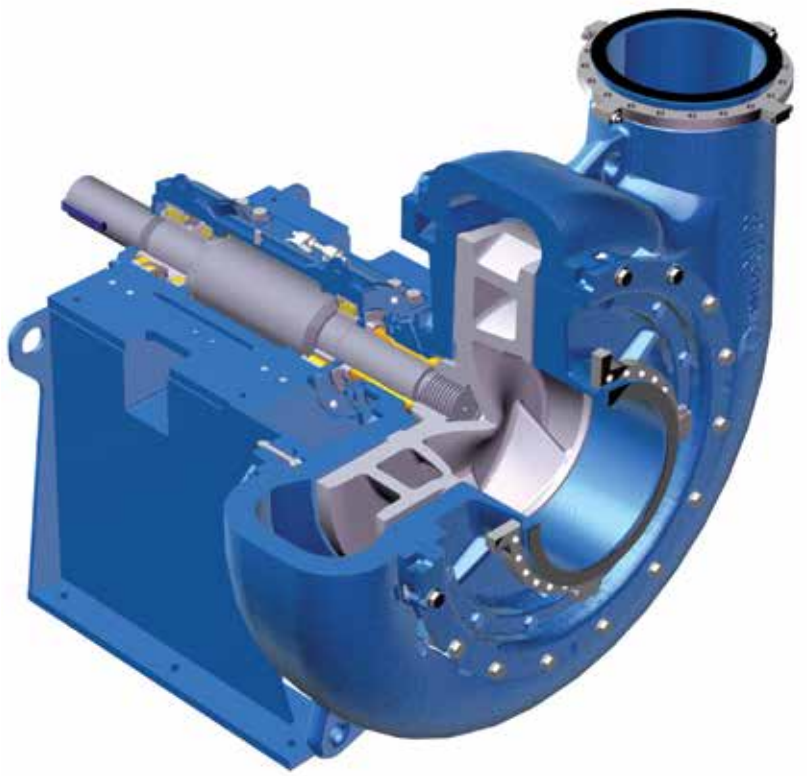



| Model | Inlet | | Outlet | | H | | L | | W1 | | W2 | | Weight * | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | inch | mm | inch | mm | inch | mm | inch | mm | inch | mm | inch | kg | lb |
| MDM300 | 300 | 12 | 250 | 10 | 1400 | 55,1 | 2246 | 88,4 | 900 | 35,4 | 1485 | 58,5 | 4845 | 10660 |
| MDM350 | 350 | 14 | 300 | 12 | 1750 | 68,9 | 2473 | 97,3 | 1000 | 39,4 | 1678 | 66,1 | 7655 | 16840 |
| MDM400 | 400 | 16 | 350 | 14 | 1940 | 76,4 | 2876 | 113,2 | 1300 | 51,2 | 1915 | 75,4 | 12065 | 26545 |
| MDM450 | 450 | 18 | 400 | 16 | 2020 | 79,5 | 2940 | 115,7 | 1300 | 51,2 | 2104 | 82,8 | 14245 | 31335 |
| MDM500 | 500 | 20 | 450 | 18 | 2145 | 84,4 | 3042 | 119,7 | 1300 | 51,2 | 2380 | 93,7 | 18105 | 39830 |
| MDM550 | 550 | 22 | 450 | 18 | 2145 | 84,4 | 3059 | 120,4 | 1300 | 51,2 | 2380 | 93,7 | 18130 | 39885 |
| MDR300 | 300 | 12 | 250 | 10 | 1300 | 51,2 | 1830 | 72,0 | 940 | 37,0 | 1519 | 59,8 | 3045 | 6700 |
| MDR350 | 350 | 14 | 300 | 12 | 1346 | 53 | 2215 | 87,2 | 900 | 35,4 | 1772 | 69,8 | 4680 | 10300 |
| MDR400 | 400 | 16 | 350 | 14 | 1940 | 76,4 | 2876 | 113,2 | 1300 | 51,2 | 1915 | 75,4 | 10610 | 23395 |
| MDR450 | 450 | 18 | 400 | 16 | 2020 | 79,5 | 2940 | 115,7 | 1300 | 51,2 | 2227 | 87,7 | 12525 | 27560 |
| MDR500 | 500 | 20 | 450 | 18 | 2145 | 84,4 | 3042 | 119,8 | 1300 | 51,2 | 2519 | 99,2 | 17460 | 38415 |
| MDR550 | 550 | 22 | 450 | 18 | 2145 | 84,4 | 3059 | 120,4 | 1300 | 51,2 | 2519 | 99,2 | 17470 | 38435 |

* Bare shaft pump weight

# *Slurry pump range XM*

## *The Thomas series of extra heavy duty hard metal slurry pumps*





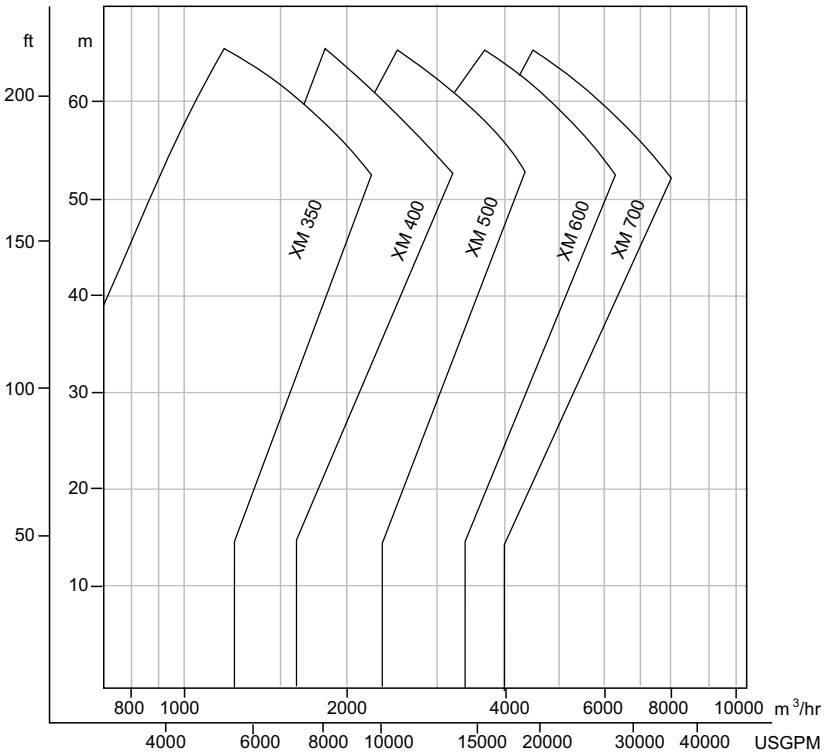
### *Summary of design features*

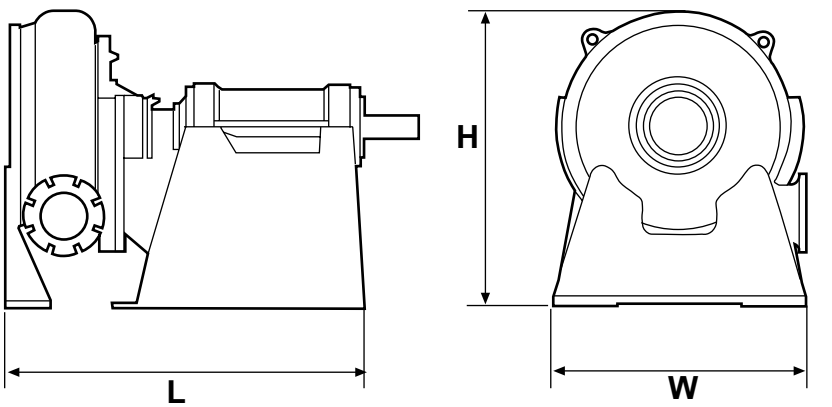
- Modular design technology
- Robust construction designed for highly abrasive, maximum duty
- Thick volute casings and heavy duty solids handling impellers, with high aspect ratio, and carefully matched, high efficiency, hydraulics for even wear
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance
- Self contained bearing cartridge assembly with oversized shaft and grease/oil lubricated anti-friction bearings
- Various shaft seal options
- Ease of maintenance
- Maintenance slide base option

See technical data on next page.

# *Slurry pump – XM*

## *Selection chart*




| Model | Inlet mm (inch) | Outlet mm (inch) | H mm (inch) | L mm (inch) | W mm (inch) | Weight* ton | Weight* lb |
|---|---|---|---|---|---|---|---|
| XM350 | 350 (14) | 300 (12) | 1 727 (68) | 1 808 (71) | 1 110 (44) | 5,0 | 11 023 |
| XM400 | 400 (16) | 350 (14) | 1 881 (74) | 1 980 (78) | 1 204 (47) | 6,7 | 14 770 |
| XM500 | 500 (20) | 450 (18) | 2 150 (85) | 2 145 (84) | 1 380 (54) | 9,8 | 21 649 |
| XM600 | 600 (24) | 550 (22) | 2 468 (97) | 2 308 (91) | 1 566 (62) | 14,9 | 33 014 |
| XM700 | 700 (28) | 650 (26) | 2 560 (100) | 2 324 (91) | 1 565 (62) | 19,9 | 43 940 |

* Bare shaft weight

# *Slurry pump range XR and VASA HD*

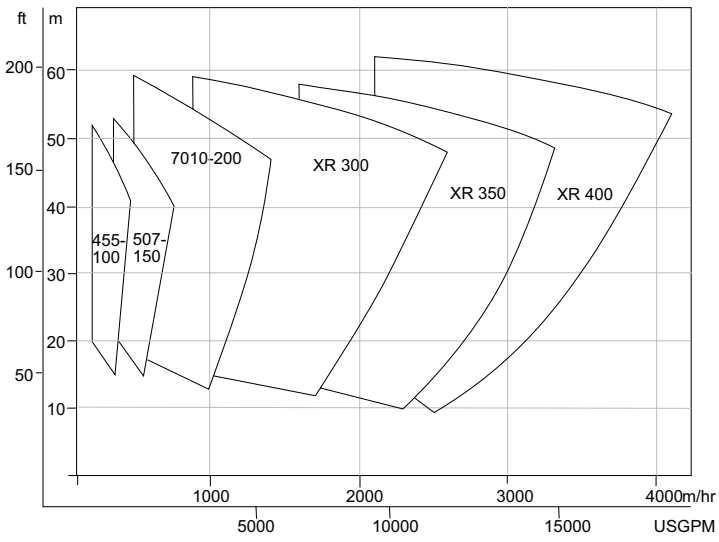
## *The Thomas and Sala series of extra heavy duty rubber lined slurry pumps*

## *Summary of design features*

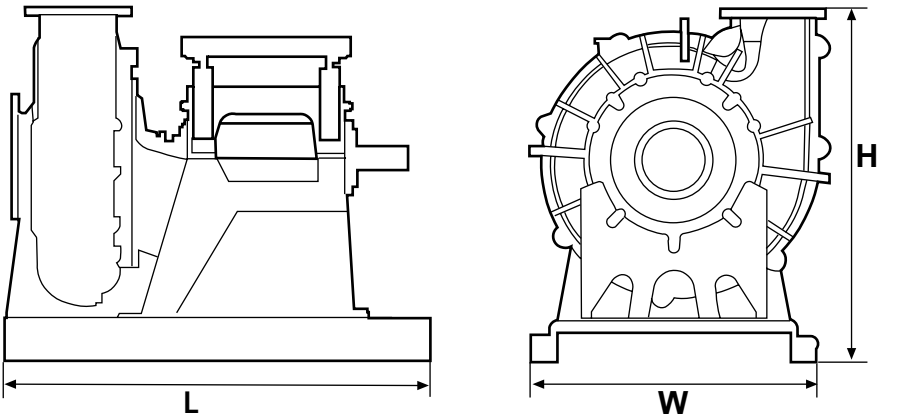
- Modular design technology
- Robust construction, with "back pull-out" feature, designed for highly abrasive, maximum duty and aggressive environments
- Maintenance slide base
- Thick volute casing liners and heavy duty solids handling impellers with high aspect ratio, and carefully matched, high efficiency, hydraulics for even wear
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance.
- Self-contained bearing cartridge assembly with oversized shaft and grease lubricated anti-friction bearings
- Various shaft seal options
- Ease of maintenance

See data sheets on next page.

## *Selection chart*



## *Slurry pump – XR*

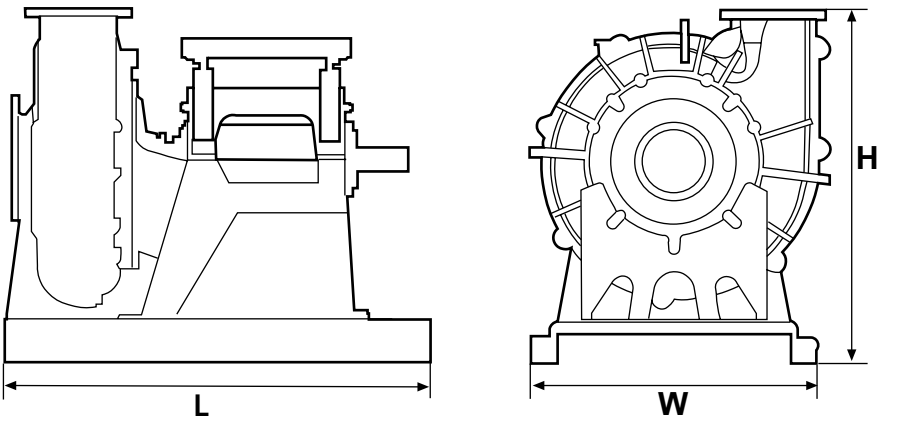



| Model | Inlet mm (inch) | Outlet mm (inch) | H mm (inch) | L mm (inch) | W mm (inch) | Weight* ton | lb |
|---|---|---|---|---|---|---|---|
| XR300 | 300 (12) | 250 (10) | 1340 (53) | 1827 (72) | 940 (37) | 3,0 | 6 720 |
| XR350 | 350 (14) | 300 (12) | 1 727 (68) | 1 808 (71) | 1 110 (44) | 4,2 | 9 305 |
| XR400 | 400 (16) | 350 (14) | 1 881 (74) | 1 980 (78) | 1 204 (47) | 5,3 | 11 823 |

* Bare shaft weight



## *Slurry pump – VASA HD*

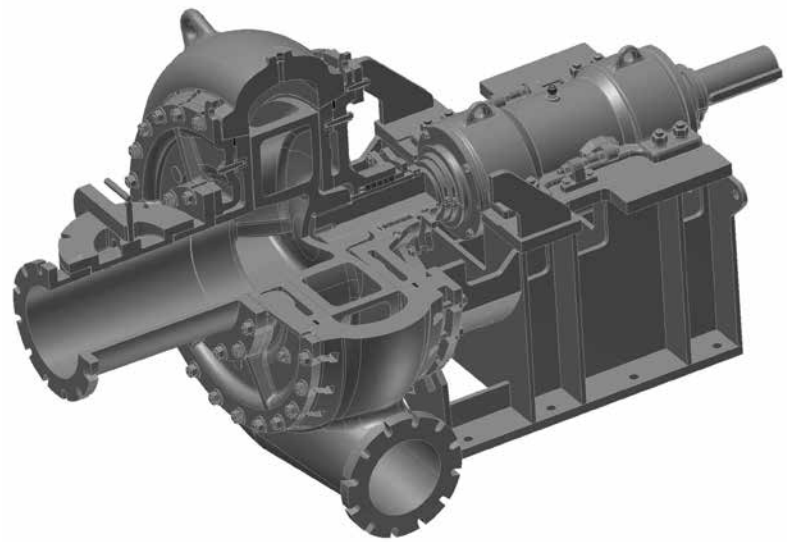



| Model | Inlet mm (inch) | Outlet mm (inch) | H mm (inch) | L mm (inch) | W mm (inch) | Weight* ton | lb |
|---|---|---|---|---|---|---|---|
| VASA HD455-100 | 150 (6) | 100 (4) | 825 (33) | 1171 (46) | 610 (24) | 0,9 | 2 016 |
| VASA HD507-150 | 200 (8) | 150 (6) | 1 055 (42) | 1 554 (61) | 700 (28) | 1,5 | 3 360 |
| VASA HD7010-200 | 250 (10) | 200 (8) | 1 400 (55) | 1 724 (68) | 950 (37) | 2,9 | 6 496 |

* Bare shaft weight

# Dredge pumps

## Thomas "Simplicity" series dredge pumps



## Summary of design features

- Optional rotation – Right or left hand rotation
- Optional discharge positions
- Suction adapter with clean out
- Three and four vane impellers available
- Amor-lok seal on the side liners for metal to metal fit
- Knock out ring for easy impeller removal
- Wide range of alloys for pump wear parts
- Over size bearings and shaft for longer life
- Cantilevered design
  - Less shaft deflection
  - Better packing and bearing life
  - 360º crescent support
  - No case feet required

See datasheet on next page.

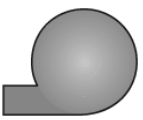
| Pump size | No. of vanes | Maximum |
|---|---|---|
| 8x6 F24 | 3 | 4.5" |
| 8x6 F24 | 4 | 4.0" |
| 10x8 H30 | 3 | 6.0" |
| 10x8 H30 | 4 | 5.5" |
| 12x10 J36 | 3 | 6.7" |
| 12x10 J36 | 4 | 5.8" |
| 14x12 L40 | 3 | 6.9" |
| 14x12 L40 | 4 | 6.0" |
| 16X14 N40 | 3 | 6.9" |
| 16X14 N40 | 4 | 6.0" |
| 18X16 P40WD | 3 | 9.8" |

| Pump size | No. of vanes | Maximum |
|---|---|---|
| 18x16 P40WD | 4 | 7.4" |
| 18x16 P46 | 3 | 9.8" |
| 18x16 P46 | 4 | 7.4" |
| 22x20 T46WD | 3 | 12.5" |
| 22x20 T46WD | 4 | 8.5" |
| 22x20 T52ND | 4 | 9.0" |
| 22x20 T52WD | 3 | 12.5" |
| 22x20 T52WD | 4 | 10.0" |
| 24x24 T52WD | 3 | 12.5" |
| 24x24 T52WD | 4 | 10.0" |

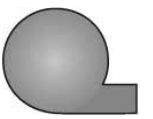
## *Dredge pumps – Thomas*

| | | Deck mounted pumps | | | | | | Underwater pumps | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pump size Inches | Impeller size Inches | 12 ft./sec velocity *GPM | 12 ft./sec velocity **TPH | 17 ft./sec velocity *GPM | 17 ft./sec velocity **TPH | 21 ft./sec velocity *GPM | 21 ft./sec velocity **TPH | 17 ft./sec Velocity TPH *GPM | TPH min. | TPH max. |
| 4 | 18,00 | 480 | 17.6 | 680 | 39 | 830 | 62 | N/A | N/A | N/A |
| 6 | 24,00 | 1058 | 39 | 1 540 | 88 | 1 900 | 108 | 1 540 | 154 | 193 |
| 8 | 30,00 | 1880 | 69 | 2 650 | 151 | 3 280 | 246 | 2 650 | 265 | 332 |
| 10 | 36,40 | 2940 | 108 | 4 160 | 237 | 5 190 | 389 | 4 160 | 416 | 520 |
| 12 | 36,40 | 4230 | 155 | 6 000 | 342 | 7 390 | 553 | 6 000 | 600 | 750 |
| 14 | 36,40 | 5160 | 190 | 7 300 | 417 | 9 025 | 700 | 7 300 | 730 | 913 |
| 16 | 40,46 | 6830 | 250 | 9 600 | 547 | 12 000 | 899 | 9 600 | 960 | 1 200 |
| 18 | 46,00 | 8640 | 317 | 12 400 | 706 | 15 190 | 1137 | 12 400 | 1 240 | 1 550 |
| 20 | 46,52 | 10 820 | 397 | 15 400 | 877 | 19 000 | 1423 | 15 400 | 1 540 | 1 925 |
| 24 | 52,00 | 15 000 | 550 | 22 400 | 1 275 | 28 000 | 2097 | 22 400 | 2 240 | 2 800 |

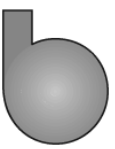
** Gallons per minute **Tons per hour of coarse sand*



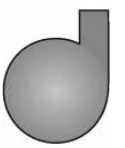
Left-hand
Bottom discharge
Left-hand rotation



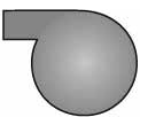
Right-hand
Bottom discharge
Right-hand rotation



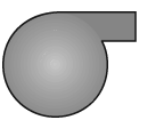
Left-hand
Top vertical discharge
Left-hand rotation



Right-hand
Top vertical discharge
Right-hand rotation



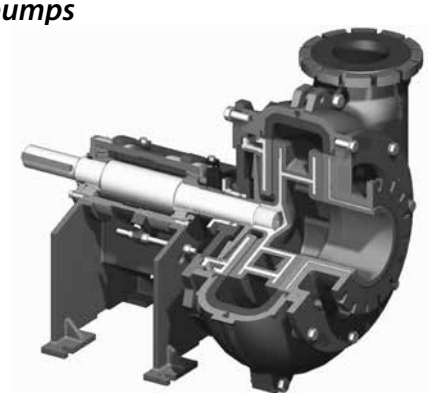
Left-hand
Top horizontal discharge
Right-hand rotation



Right-hand
Top horizontal discharge
Left-hand rotation

# Slurry pump range HR and HM

## The Orion series of heavy duty rubber lined and hard metal slurry pumps



*HR wet end*

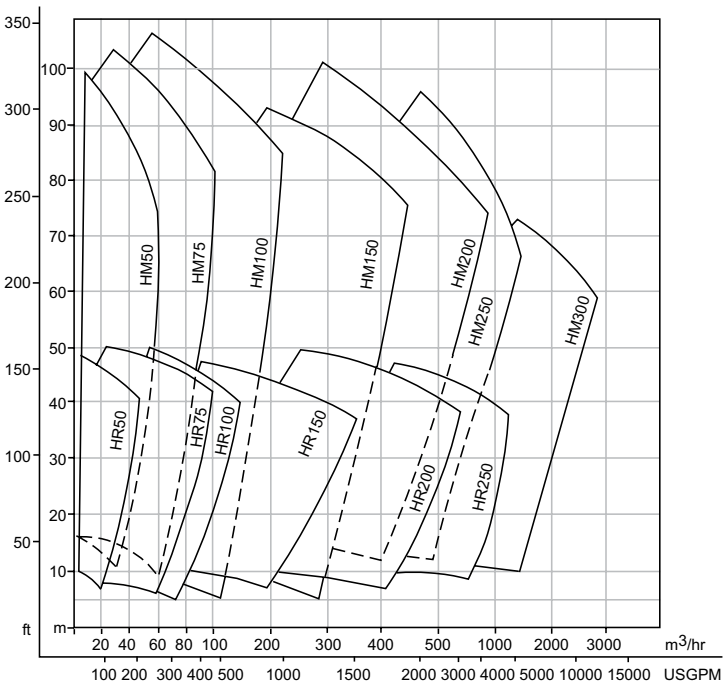
*HM wet end*

## Summary of design features

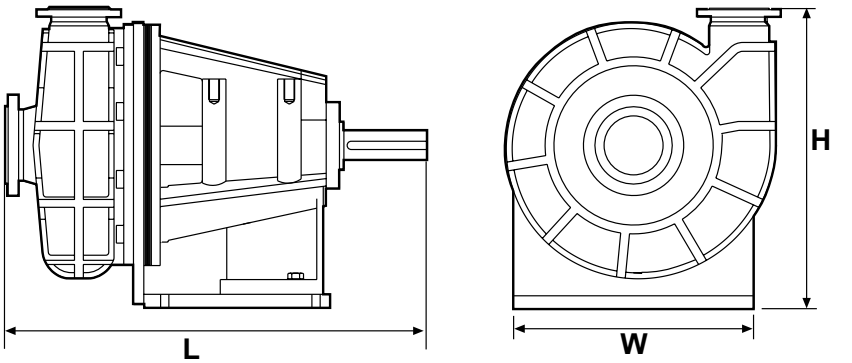
- Modular design technology and back pull-out feature
- Robust construction
- Thick volute casing/liner and solids handling, large diameter, impeller with carefully matched, high efficiency, hydraulics for even wear
- Double adjustment for sustained efficiency
- Materials used are the very best available, providing both excellent wear properties and corrosion resistant
- Self-contained bearing cartridge assembly with oversized pump shaft and anti-friction bearings
- Various shaft seal options
- Ease of maintenance

See data sheet on next page.

## Selection chart



## *Slurry pump range – HR*

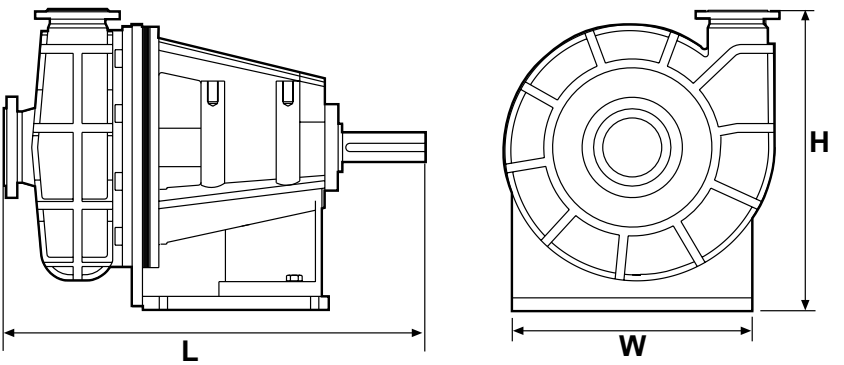



| | Connection dimensions | | | | General dimensions | | | | | | Total weight* | | Total weight* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet | | Outlet | | H | | L | | W | | Double adjustm. | | Single adjustm. | |
| Model | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | kg | (lbs) | kg | (lbs) |
| HR50 | 50 | (2) | 32 | (1,5) | 428 | (17) | 709 | (28) | 360 | (14) | 180 | (397) | 126 | (278) |
| HR75 | 75 | (3) | 50 | (2,0) | 463 | (18) | 729 | (29) | 360 | (14) | 220 | (485) | 145 | (320) |
| HR100 | 100 | (4) | 75 | (3,0) | 555 | (22) | 913 | (36) | 424 | (17) | 330 | (728) | 270 | (595) |
| HR150 | 150 | (6) | 100 | (4,0) | 713 | (28) | 1 097 | (43) | 545 | (21) | 630 | (1 389) | 510 | (1 124) |
| HR200 | 200 | (8) | 150 | (6,0) | 965 | (38) | 1 295 | (51) | 686 | (27) | 1 250 | (2 756) | 1 065 | (2 348) |
| HR250 | 250 | (10) | 200 | (8,0) | 1 125 | (44) | 1 550 | (61) | 830 | (33) | 2 110 | (4 652) | 1 715 | (3 781) |

**Bare shaft weight*

## *Slurry pump range – HM*



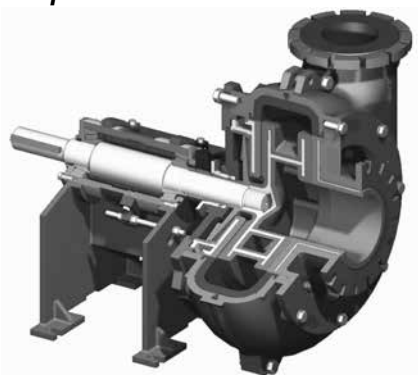



| | Connection dimensions | | | | General dimensions | | | | | | Total weight* | | Total weight* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet | | Outlet | | H | | L | | W | | Double adjustm. | | Single adjustm. | |
| Model | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | kg | (lbs) | kg | (lbs) |
| HM50 • | 50 | (2) | 32 | (1,5) | 433 | (17) | 713 | (28) | 360 | (14) | 160 | (353) | 136 | (300 |
| HM75 • | 75 | (3) | 50 | (2,0) | 438 | (17) | 734 | (29) | 360 | (14) | 200 | (441) | 161 | (355) |
| HM100 • | 100 | (4) | 75 | (3,0) | 505 | (20) | 880 | (35) | 424 | (179 | 320 | (705) | 250 | (551) |
| HM150 • | 150 | (6) | 100 | (4,0) | 630 | (25) | 1 025 | (40) | 545 | (21) | 550 | (1 213) | 440 | (970) |
| HM200 | 200 | (8) | 150 | (6,0) | 855 | (34) | 1 258 | (50) | 686 | (27) | 1 220 | (2 690) | 1 010 | (2 227) |
| HM250 | 250 | (10) | 200 | (8,0) | 1 030 | (41) | 1 463 | (58) | 830 | (33) | 2 040 | (4 497) | 1 660 | (3 660) |
| HM300 | 300 | (12) | 250 | (10,0) | 1 150 | (45) | 1 591 | (63) | 1 000 | (39) | 2850 | (6 283) | 1 900 | (4 189) |

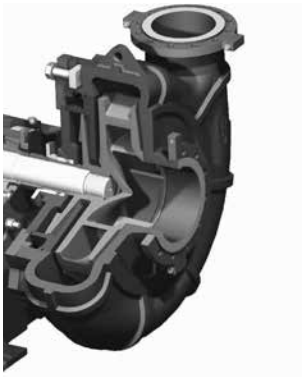
**Bare shaft weight* • These pumps are available with fully recessed induced vortex impeller.

# *Slurry pump range MR and MM*

## *The Orion series of mining duty rubber lined and hard metal slurry pumps*



*MR Wet End*



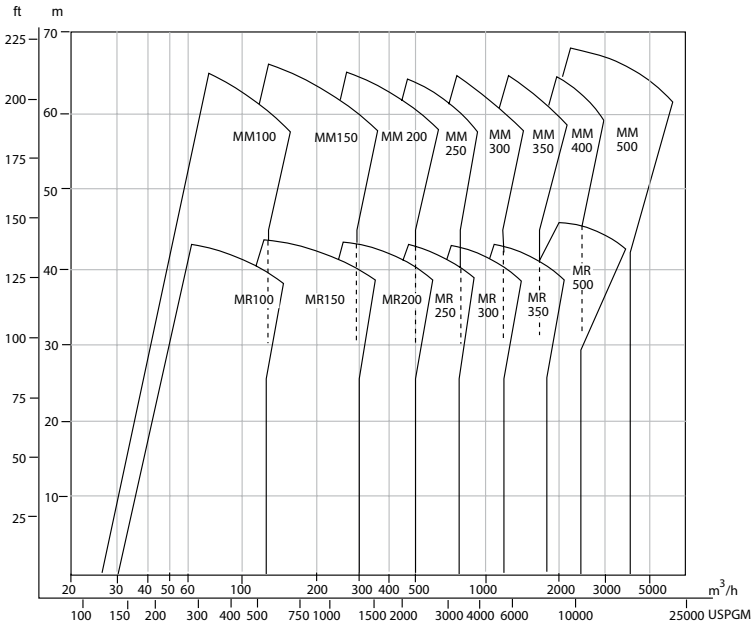
*MM Wet End*

## *Summary of design features*

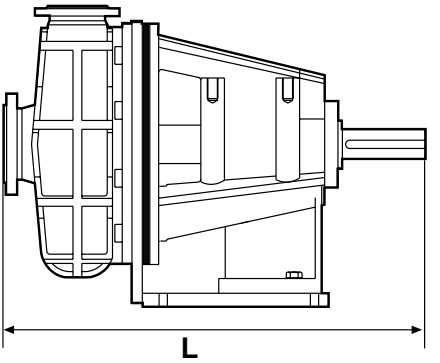
- Modular design technology and back pull-out feature
- Robust construction
- Solids handling, medium diameter, impeller with carefully matched, high efficiency, hydraulics for even wear
- Double adjustment for sustained efficiency
- Materials used are the very best available, providing both excellent wear properties and corrosion resistant
- Self contained bearing cartridge assembly with oversized pump shaft and grease lubricated taper roller bearings
- Various shaft seal options
- Ease of maintenance
- Maintenance slide base option

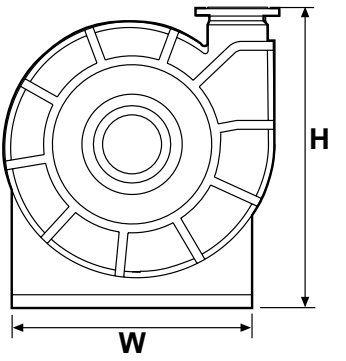
See data sheet on next page.

## *Selection chart*



## *Slurry pump – MR*



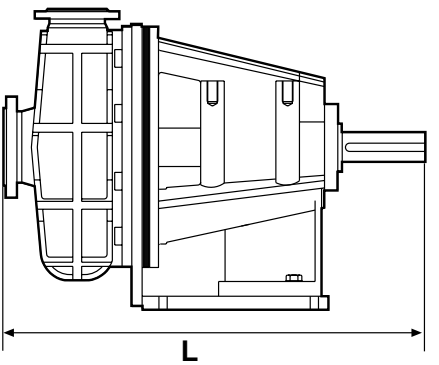



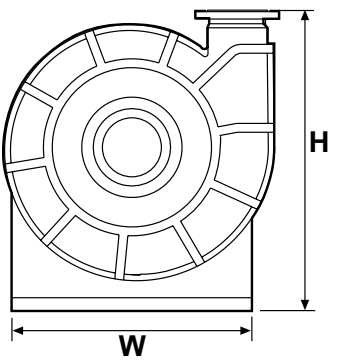

| | Connection dimensions | | | | General dimensions | | | | | | Total weight* | | Total weight* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet | | Outlet | | H | | L | | W | | Double adjustm. | | Single adjustm. | |
| Model | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | kg | (lbs) | kg | (lbs) |
| MR100 | 100 | (4) | 75 | (3) | 456 | (18) | 741 | (29) | 360 | (14) | 260 | (573) | 150 | (331) |
| MR150 | 150 | (6) | 100 | (4) | 507 | (20) | 919 | (36) | 424 | (17) | 420 | (926) | 270 | (595) |
| MR200 | 200 | (8) | 150 | (6) | 683 | (27) | 1 092 | (43) | 545 | (21) | 740 | (1 631) | 490 | (1 080) |
| MR250 | 250 | (10) | 200 | (8) | 878 | (35) | 1 303 | (51) | 686 | (27) | 1 540 | (3 395) | 960 | (2 116) |
| MR300 | 300 | (12) | 250 | (10) | 1 035 | (41) | 1 506 | (59) | 830 | (33) | 2 450 | (5 401) | 1 520 | (3 351) |
| MR350 | 350 | (14) | 300 | (12) | 1 257 | (49) | 1 665 | (66) | 1 000 | (39) | — | — | 1 600 | (5 732) |
| MR500 | 489 | (20) | 438 | (18) | 2 064 | (81) | 2 689 | (106) | 1 204 | (47) | — | — | 8 030 | (17 703) |

**Bare shaft pump weight*

## *Slurry pump – MM*






| | Connection dimensions | | | | General dimensions | | | | | | Total weight* | | Total weight* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet | | Outlet | | H | | L | | W | | Double adjustm. | | Single adjustm. | |
| Model | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | mm | (inch) | kg | (lbs) | kg | (lbs) |
| MM100 • | 100 | (4) | 75 | (3) | 454 | (18) | 730 | (29) | 360 | (14) | 230 | (507) | 170 | (375) |
| MM150 • | 150 | (6) | 100 | (4) | 527 | (21) | 889 | (35) | 424 | (17) | 370 | (816) | 275 | (606) |
| MM200 • | 200 | (8) | 150 | (6) | 710 | (28) | 1 073 | (42) | 545 | (21) | 650 | (1 433) | 525 | (1 157) |
| MM250 | 250 | (10) | 200 | (8) | 885 | (35) | 1 245 | (49) | 686 | (27) | 1 350 | (2 976) | 1 095 | (2 414) |
| MM300 | 300 | (12) | 250 | (10) | 1 055 | (42) | 1 483 | (58) | 830 | (33) | 2 150 | (4 740) | 1 775 | (3 913) |
| MM350 | 350 | (14) | 300 | (12) | 1 080 | (43) | 1 527 | (60) | 830 | (33) | 2 300 | (5 071) | 1 960 | (4 321) |
| MM400 | 400 | (16) | 350 | (14) | 1 250 | (49) | 1 620 | (64) | 1 000 | (39) | 3 000 | (6 614) | 2105 | (4 641) |
| MM500 | 500 | (20) | 450 | (18) | 1 726 | (68) | 2 180 | (86) | 1 110 | (44) | — | — | 5 980 | (13 184) |

**Bare shaft weight* • These pumps are available with fully recessed induced vortex impeller.

# *Slurry pump range VS*

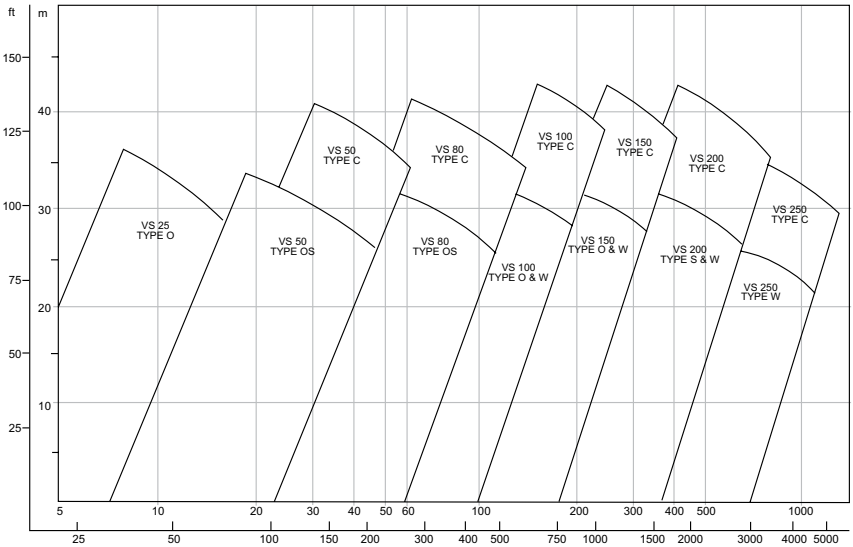
## *The Sala series of vertical sump pumps*

## *Summary of design features*

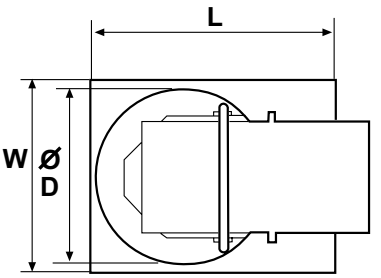
- Simple installation
- Cantilever design without submerged bearings or shaft seal
- Bearing assembly with double protection sealing arrangement to prevent ingress of slurry
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance
- Wear parts are available in a variety of different materials with full interchangeability
- Range of impeller options

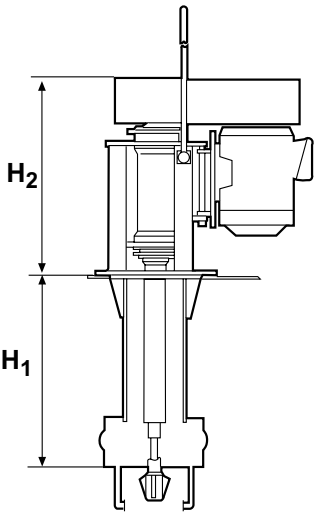
See data sheet on next page

## *Selection chart*



## *Slurry pump – VS (Vertical sump pumps)*




| Model* | | $H_1$ mm (inch) | $H_2$ mm (inch) | D mm** mm (inch) | L** mm (inch) | W** mm (inch) | Weight*** kg/lb |
|---|---|---|---|---|---|---|---|
| VS25 | (1) | 800 (32) | 585 (23) | 400 (15¾) | | | 130/287 |
| VS25 | (1) | 1200 (48) | 865 (34) | 530 (20¾) | | | 350/772 |
| VS25 | (1) | 1500(60) | 865 (34) | 530 (20¾) | | | 375/827 |
| VS25 | (1) | 1800 (72) | 865 (34) | 530 (20¾) | | | 395/871 |
| VS50 ● | (2) | 800 (32) | 585 (23) | 400 (15¾) | | | 220/485 |
| VS50 ● | (2) | 1200 (48) | 865 (34) | 530 (20¾) | | | 480/1 058 |
| VS50 ● | (2) | 1500 (60) | 865 (34) | 530 (20¾) | | | 510/1 124 |
| VS50 ● | (2) | 1800 (72) | 865 (34) | 530 (20¾) | | | 540/1 190 |
| VS80 | (3) | 800 (32) | 870 (34¼) | 530 (20¾) | | | 435/959 |
| VS80 ● | (3) | 1 200 (48) | 975 (38½) | 565 (22¼) | | | 545/1 202 |
| VS80 ● | (3) | 1 500 (60) | 975 (38½) | 565 (22¼) | | | 580/1 279 |
| VS80 ● | (3) | 1 800 (72) | 975 (38½) | 565 (22¼) | | | 615/1 356 |
| VS100 | (4) | 8 00 (32) | 850 (33½) | 530 (20¾) | | | 465/1 025 |
| VS100 ● | (4) | 1 200 (48) | 960 (37¾) | 565 (22¼) | | | 575/1 268 |
| VS100 ● | (4) | 1 500 (60) | 960 (37¾) | 565 (22¼) | | | 610/1 345 |
| VS100 ● | (4) | 1 800 (72) | 960 (37¾) | 565 (22¼) | | | 645/1 422 |
| VS150 ● | (6) | 1 200 (48) | 965 (38) | 565 (22¼) | | | 680/1 499 |
| VS150 ● | (6) | 1 500 (60) | 1 285 (50½) | | 800 (31½) | 800 (31½) | 1 415/3 120 |
| VS150 ● | (6) | 1 800 (72) | 1 285 (50½) | | 800 (31½) | 800 (31½) | 1 470/3 241 |
| VS200 ● | (8) | 1 200 (48) | 1 285 (50½) | | 800 (31½) | 800 (31½) | 1 675/3 693 |
| VS200 ● | (8) | 1 500 (60) | 1 285 (50½) | | 800 (31½) | 800 (31½) | 1 725/3 803 |
| VS200 ● | (8) | 1 800 (72) | 1 285 (50½) | | 800 (31½) | 800 (31½) | 1 775/3 913 |
| VS250 ● | (10) | 1 500 (60) | 1 420 (56) | | 800 (31½) | 800 (31½) | 2 200/4 850 |
| VS250 ● | (10) | 1 800(72) | 1 420 (56) | | 800 (31½) | 800 (31½) | 2 280/5 027 |

*VS25 (1) = Vertical sump; 25 = outlet mm; (1) = outlet inch

** ØD or LxW is the pump base plate dimension. Optional base plate incl. discharge pipe also available.

*** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

● These pumps are available in acid proof version with all wetted parts fully covered with natural rubber or chloroprene.

# *Slurry pump range VSHM and VSMM*

## *The Sala series of vertical sump pumps*

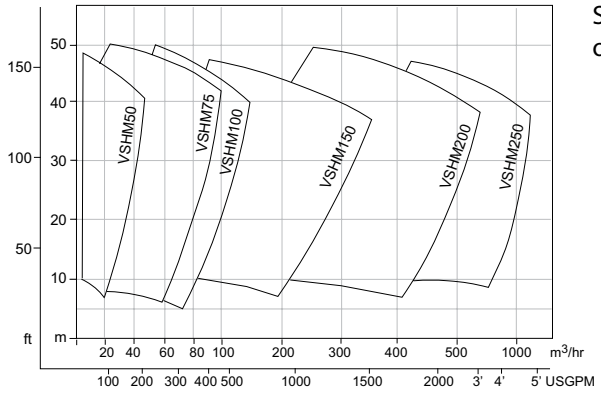
The VSH and VSM pumps are a new combination of our classic VS sump pumps and our Orion series horizontal pump wet ends.

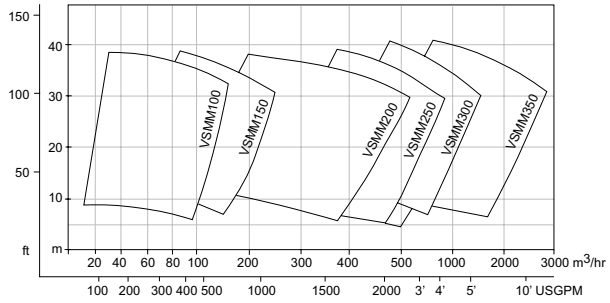
This provides a major advantage: the same wet end parts are used for both horizontal slurry pumps and sump pumps, thus reducing parts inventory and simplifying maintenance.

It does also make it possible to generate a higher TDH, pump head.



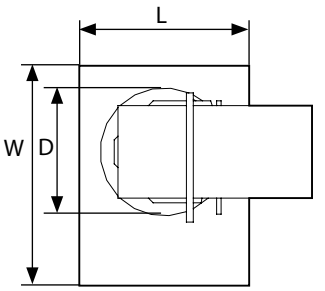
## *Selection chart*

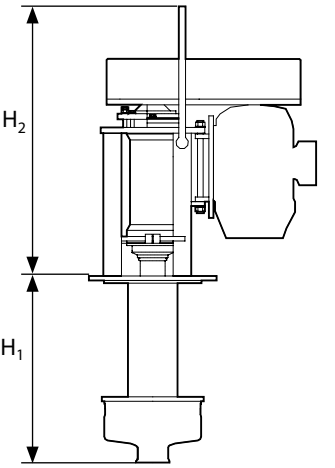



See data sheet on next page.

# *Slurry pump range VSHM / VSMM / VSHR – (Vertical sump pumps)*




| Pump size | Outlet mm (inch) | $H_2$* mm (inch) | D** mm (inch) | L Opt. base plate mm (inch) | W mm (inch) | Weight *** kg | Weight *** lb |
|---|---|---|---|---|---|---|---|
| VSHM50 | ● 32 (1,25) | 87 (34) | Ø 530 (20¾) | 600 (23½) | 600 (23½) | 390/405/420 | 860/893/926 |
| VSHR50 | 32 (1,25) | 87 (34) | Ø 530 (20¾) | 600 (23½) | 600 (23½) | 380/395/410 | 838/871/904 |
| VSHM75 | ● 50 (2) | 87 (34) | Ø 530 (20¾) | 600 (23½) | 600 (23½) | (L120) 415 | 915 |
| VSHM75 | ● 50 (2) | 98 (38) | Ø 565 (22¼) | 600 (23½) | 600 (23½) | (L150/180) 530/565 | 1 168/1 245 |
| VSHR75 | 50 (2) | 87 (34) | Ø 530 (20¾) | 600 (23½) | 600 (23½) | 399/424/449 | 880/935/990 |
| VSHM100 | ● 75 (3) | 98 (38) | Ø 565 (22¼) | 750( 29½) | 600 (23½) | 535/565/605 | 1 180/1 246/1334 |
| VSHR100 | 75 (3) | 98 (38) | Ø 565 (22¼) | 750 (29½) | 600 (23½) | 555/585/625 | 1 224/1 290/1378 |
| VSHM150 | ● 100 (4) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 314/1366/1418 | 2 897/3 012/3127 |
| VSHR150 | 100 (4) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 405/1460/1515 | 3 098/3 219/3340 |
| VSHM200 | 150 (8) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 650/1710/1770 | 3 638/3 770/3903 |
| VSHR200 | 150 (8) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 680/1740/1796 | 3 704/3 836/3960 |
| VSHM250 | 200 (10) | 142 (56) | □800 (31½) | 1 360 (53½) | 1 220 (48) | 2 310/2400/2480 | 5 093/5 291/5468 |
| VSHR250 | 200 (10) | 142 (56) | □800 (31½) | 1 360 (53½) | 1 220 (48) | 2 365/2455/2535 | 5 214/5 413/5589 |
| VSMM100 | ● 75 (3) | 87 (34) | Ø 530 (20¾) | 600 (23½) | 600 (23½) | 430/465/500 | 948/1 025/1103 |
| VSMM150 | ● 100 (4) | 98 (38) | Ø 565 (22¼) | 750 (29½) | 600 (23½) | 560/590/630 | 1 235/1 301/1389 |
| VSMM200 | ● 150 (6) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 390/1445/1500 | 3 065/3 186/3307 |
| VSMM250 | 200 (10) | 128 (50) | □800 (31½) | 1 200 (47¼) | 900 (35½) | 1 720/1780/1840 | 3 792/3 925/4057 |
| VSMM300 | 300 (12) | 142 (56) | □800 (31½) | 1 360 (53½) | 1 220 (48) | 2 490/2570/2650 | 5 490/5 666/5843 |
| VSMM350 | 300 (14) | 142 (56) | □800 (31½) | 1 360 (53½) | 1 220 (48) | – /2745/2825 | – /6 052/6 228 |

*Frame length ($H_1$) is available in 120, 150, 180 cm (48, 60, 72 inch) except VSMM350 which is available in 150, 180 cm (60, 72 inch).

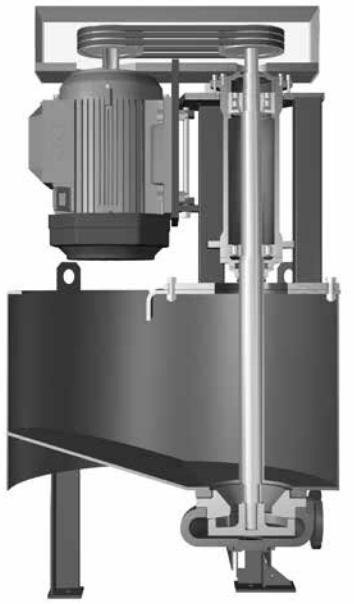
** D Ø or □ is bearing frame base plate. Larger optional base plate or mounting plate incl. discharge pipe also available.

*** Weight figures are for metal parts, and for different frame lengths (L120 / L150 / L180).

● These pumps are available with the fully recessed induced vortex impeller.

# *Slurry pump range VT*

## *The Sala series of vertical tank pumps*

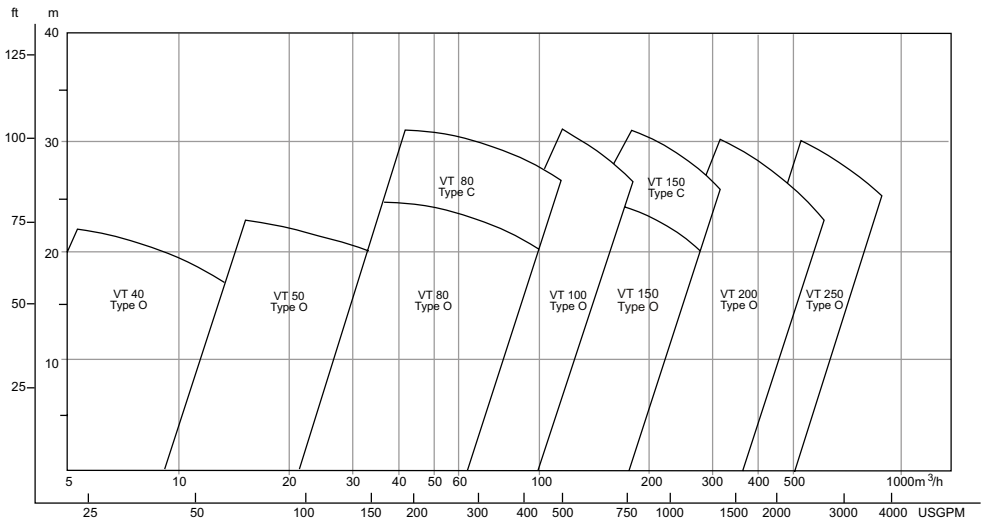


## *Summary of design features*

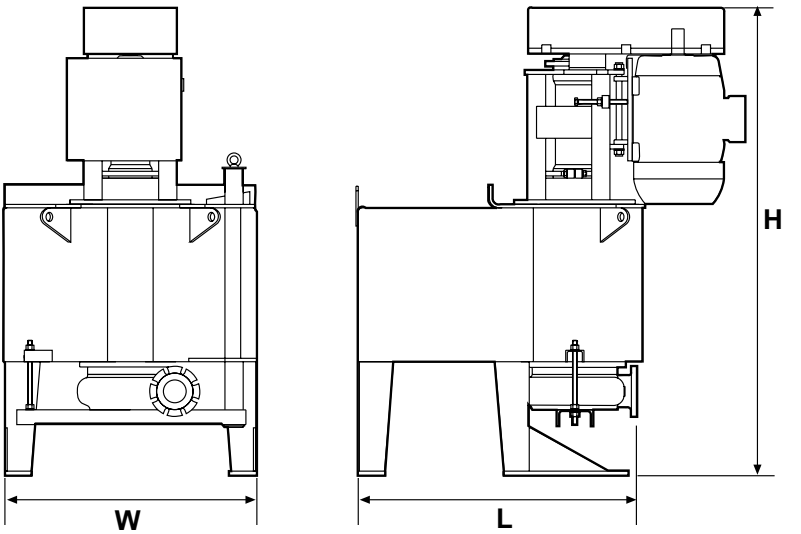
- Pump, pump sump and motor in one integrated unit for flexible layout and simple installation.
- Open sump and vertical inlet prevents air blocking and gives a smooth operation.
- Oversize bearings, for added life and minimum maintenance. Double protection sealing arrangement against penetration of slurry.
- Cantilever shaft with no submerged bearings or seals. Shaft made of alloy steel, for superior strength and toughness.
- Easily replaced wear parts and metal/rubber interchangeability.

## *Selection chart*

See data sheet on next page.



## *Slurry pump range VT – (Vertical tank pump)*




| Model | Hmm (inch) | L mm (inch) | W mm (inch) | Weight** kg/lb | Sump volume $m^3$/USG |
|---|---|---|---|---|---|
| VT 40 (1.5) lab | 955 (37.5) | 640 (25) | 400 (16) | 90/198 | 0.03/8 |
| VT 40 (1.5) | 1 030 (40.5) | 740 (29) | 610 (24) | 110/243 | 0.06/16 |
| VT 50 (2) | 1 470 (58) | 1 035 (41) | 1 010 (40) | 305/672 | 0.25/66 |
| VT 80 (3) | 1 880 (74) | 1 015 (40) | 1 060 (42) | 580/1279 | 0.33/87 |
| VT100 (4) | 2 050 (81) | 1 225 (48) | 1 100 (43) | 825/1819 | 0.57/150 |
| VT150 (6) | 2 160 (85) | 1 285 (50.5) | 1 100 (43) | 925/2039 | 0.57/150 |
| VT200 (8) | 3 105 (122) | 1 710 (67) | 1 510 (59) | 2 655/5853 | 1.26/333 |
| VT 250 (10) | 3 105 (122) | 1 760 (69) | 1 510 (59) | 2 785/6140 | 1.26/333 |

*VT50 (2), VT = Vertical Tank, 50 (2) = outlet size mm (inch).

** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

# *Slurry pump range VF*

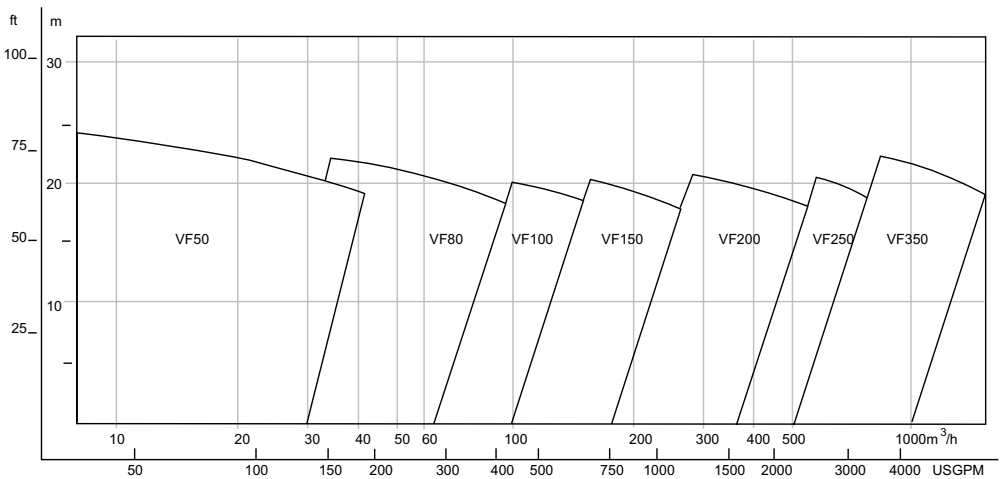
## *The Sala series of vertical froth pumps*

## *Summary of design features*

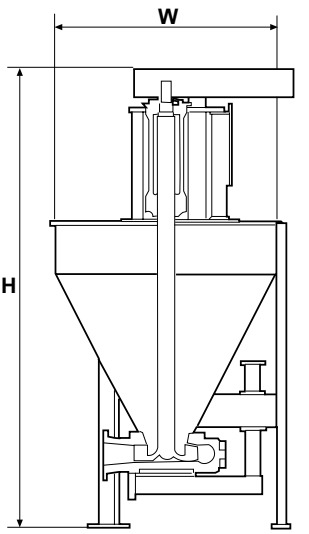
- Pump, pump sump and motor in one integrated unit for flexible layout and simple installation.
- Open sump and vertical inlet prevents air blocking.
- Oversize bearings, for added life and minimum maintenance. Double protection sealing arrangement against penetration of slurry.
- Cantilever shaft and made of alloy steel, for superior strength and toughness, with no submerged bearings or seals.
- Easily replaced wear parts and metal/rubber interchangeability.

See data sheet on next page.

## *Selection chart*



# *Slurry pump – VF (Vertical froth pump)*




| Model | Hmm (inch) | L mm (inch) | Weight** kg/lb | Sump volume $m^3$/USG |
|---|---|---|---|---|
| VF50 (2)* | 1 600 (63) | 800 (31) | 355/783 | 0.14/37 |
| VF80 (3) | 2 250 (88) | 1 000 (39) | 605/1 334 | 0.37/98 |
| VF100(4) | 2 700 (106) | 1 400 (55) | 975/2 150 | 0.82/217 |
| VF150(6) | 2 700 (106) | 1 400 (55) | 1 095/2 414 | 0.82/217 |
| VF200(8) | 3 760 (148) | 1 850 (73) | 2 700/5 952 | 2.30/607 |
| VF250(10) | 3 760 (148) | 1 850 (73) | 2 900/6 392 | 2.30/607 |
| VF350(14) | 4 500 (177) | 2 150 (85) | 5 555/12 245 | 3.50/925 |

*VF50 (2), VF = Vertical Froth, 50 (2) = outlet size mm (inch).

** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

## *Application guide for slurry pumps*

As mentioned before, the only limitation for hydraulic transportation is your own imagination.

This application guide is a simple way to find out what type of pump to be used for different slurry operations.


| | |
|---|---|
| Selection by Solids | page 8:26 |
| Selection by Head and Volume | page 8:26 |
| Selection by Slurry type | page 8:27 |


### *Selection by industrial segment*


| | |
|---|---|
| Metallic and Industrial minerals | page 8:28 |
| Construction | page 8:29 |
| Coal | page 8:30 |
| Waste & Recycling | page 8:30 |
| Power & FGD | page 8:30 |
| Pulp & Paper | page 8:31 |
| Metallurgy | page 8:31 |
| Chemical | page 8:32 |
| Mining | page 8:32 |

## Selection by solids

### Duty: Coarse particles

*Comments:* Everything larger than 5 mm is considered to be coarse.

Don't use rubber pumps, metal pumps only.

Upper practical limit in particle size is normally 50 mm.

Limitation is the impact on the impeller.

*Note:* Particle diameter max. 1/3 of the pipe diameter.

*Recommendation*: MDM , XM and HM ranges.

### Duty: Fine particles

*Comments*: If the particles are sharp - use rubber.

If particles are not sharp - use rubber or metal.

*Recommendation:* H and M ranges.

### Duty: Sharp (abrasive) particles

*Comments:* If sizes are below 5 mm - use rubber.

If particles are above 5 mm - use metal.

*Recommendation:* MD, X, H and M ranges.

### Duty: High percent solids

*Comments:* You have to be careful if the percent solids is getting close to 40% by volume. Above 50% the slurry is impossible to handle with centrifugal pumps. Only vertical tank pumps are able to handle applications with really high percent solids.

*Recommendation:* VT range.

### Duty: Low percent solids

*Comments:* Choose the lightest and most cost effective pumps.

*Recommendation:* M range.

### Duty: Fibrous particles

*Comments:* The problem is blocking of particles and air blocking. Use induced flow impellers (Vortex).

### Duty: One size particles

*Comments:* When all fine particles are removed from the slurry the solid settling rate can be critical and can call for severe derating of the pump. Pumping efficiency goes down for all pump types.

*Recommendation:* All pump ranges.

## Selection by head and volume

### Duty: High head

*Comments:* Normally metal pump applications due to the high peripheral speed on the impeller. If you need rubber lined pumps, series pumping may be needed.

Max. head on hard metal pump 125 m.

Max. head on rubber impeller 45 m.

*Note!* High rate of wear at high speeds for centrifugal pumps.

*Recommendation:* MDM, MDR , XM, XR and HM, or staged HR.

### Duty: Varying head at constant flow

*Comments:* Use a multi-speed drive or a variable (frequency control) drive.

*Recommendation:* All ranges.

### Duty: Varying flow at constant flow

*Comments:* Use variable (frequency control) drives.

*Recommendation:* All ranges.

### *Duty: High suction lift*

*Comments:* Metal pumps are preferred due to risk of rubber lining collapse on high suction lifts.

Max. practical suction lift 5 - 8 m depending on S.G.

Pumps are not self-priming, i.e. you need a priming device.

The pump and inlet pipe need to be filled with liquid before starting.

*Recommendation:* MDM, XM, HM and MM.

### *Duty: High flow*

*Comments:* Use parallel pump installations.

Risk for cavitation.

*Recommendation:* All ranges.

### *Duty: Low flow*

At low flows rubber linings can be overheated. Use metal.

Be careful if heads* are high and flow is low.

Open vertical pumps have no problems.

**BEP = Best Efficiency Point*

*Recommendation:* Try to use VS, VT and VF ranges.

### *Duty: Fluctuating flow*

*Comments:* Use horizontal pumps with variable speed drive or fixed speed vertical pumps.

*Recommendation:* VT, VF or VS. Horizontals; all types with variable speed drives.

## *Selection by slurry type*

### *Duty: Fragile slurries*

*Comments:* Use induced flow impellers (fully recessed).

Both metal and rubber pumps can be used. Both horizontal and vertical pumps can be used.

*Recommendation:* All ranges.

### *Duty: Hydrocarbon slurries (oil and reagents contaminated)*

*Comments:* Natural rubber is out.

Be careful with seal material of natural rubber. Use synthetic seals.

Use metallic pumps or wear parts in polyurethane.

*Recommendation:* All ranges.

### *Duty: High temperature (greater than 100° C) slurries*

*Comments:* (Temperature limit for natural rubber is 60° C.) See section 9 for synthetic rubbers.

Practical limit for operating temperature is 135° C. Above this temperature the bearings can be over-heated!

*Recommendation:* All horizontal ranges.

### *Duty: Frothy slurries*

*Comments:* Use a froth pump of vertical design.

*Recommendation:* VF range.

### *Duty: Hazardous slurries*

*Comments:* Warning! This case has to be referred back to the pump sales support departments.

Shaft sealing is critical from explosion point of view. Normally closed pump systems are used.

*Recommendation:* Horizontal ranges.

### *Duty: Corrosive slurries (low pH)*

*Comments:* For acidic duties use rubber or elastomer.

For metal pumps with chrome iron parts the acid limit is pH 2,5.

Sea water slurries (containing chlorides) must have a rubber pump.

*Note!* $CuSO_4$ (used in flotation circuits) is extremely corrosive, use rubber pumps.

*Recommendation:* All ranges.

### *Duty: High viscosity fluids (Newtonian)*

*Comments:* When viscosity is going up to 5 times the viscosity of water the pumping gets critical.

With this restriction basically any pump in our range can be used, if properly sized.

*Recommendation:* All sizes.

### *Duty: High viscosity fluids (non-Newtonian)*

*Comments/Recommendation:*

These applications are very tricky and should be referred back to the pump sales support staff.

### *Duty: Mixing*

*Comments:* Tank pumps are excellent as mixers.

When mixing water and solids look up the correct ratio between liquid and solids.

*Recommendation:* VT and VF range.

## *Industrial applications, minerals*

### *Application: Pumps for grinding circuits*

*Comments:* Our MD range is specially designed for grinding circuits (incl. cyclone feed).

For particles sizes below 5 mm use rubber. If possible mix flows containing coarse and fine particles together for better slurry stability.

*Recommendation:* MDR and MDM, XR and XM, HR and HM.

### *Application: Pumps for froth*

*Comments:* The VF range is specially designed for froth pumping.

Be cautious for heads greater than 15 m.

*Recommendation:* VF.

### *Application: Pumps for floor sumps*

*Comments:* Use sump pumps type VS with metallic wear parts, since there often is a risk for oversize tramp material coming into floor sumps.

If rubber must be used, put a strainer in front of the pump or around the pump.

*Recommendation:* VS range.

### *Application: Pumps for tailing*

*Comments:* Depending on particle size both rubber and metal pumps can be used. For long distances installations use multiple pumps in series.

*Recommendation:* MD, X and H ranges, both rubber and metal.

### *Application: Pumps for hydro-cyclone feed*

*Comments:* For sharp classification use horizontal pumps type MD, X or H. For dewatering cyclones use tank pumps.

*Recommendation:* MD, X, H and VT ranges.

### *Application: Pumps for pressure filter feed*

*Comments:* High head needed with variable speed control (alternatively two-speed drive).

Avoid rubber due to low flow head build up.

### *Application: Pumps for tube press feed*

*Comments:* Small flow and high head, use metal pumps of type HM.

One pump can feed many tubes by a slurry distribution ring.

*Recommendation:* HM range.

### *Application: Pumps for leaching*

*Comments:* See corrosive slurries, page 8:28.

### *Application: Pumps for dense media (heavy media)*

*Comments:* High inlet head and high percent solids in combination with low discharge head can cause expeller seal leakage problems.

*Recommendation:* HM range.

### *Application: Pumps for general purpose (mineral)*

*Comments:* Horizontal pumps of type MM and MR are ideal for normal duty in mineral process circuits. If the wear is extreme, use the X and H ranges.

Rubber is normally preferred in "hard rock" concentrators.

For special applications use the vertical pumps.

*Recommendation:* All ranges.

## *Industrial applications, construction*

### *Application: Pumps for wash water (sand and gravel)*

*Comments:* Normally, the vertical pumps type VS and VT are used. Horizontal pump of the M range is also suitable.

*Recommendation:* V and M range.

### *Application: Pumps for sand transportation*

*Comments:* Horizontal pumps with rubber lining are preferred.

*Recommendation:* MR.

### *Application: Pumps for tunnel dewatering*

*Comments:* As front pumps use drainage pumps. For the first transportation stage vertical pump type VS is normally used.

For horizontal distant pumping use HM range.

For cuttings from full face boring (TBM:s) use HM and MM pumps.

For small tunnels (micro bore) use small HM.

*Recommendation:* H, M and VS range. (No rubber due to oil.)

## *Industrial applications, coal*

### *Application: Pumps for coal washing*

Comments: Generally metal pumps are used because of risk for oversized tramp material.

*Recommendation:* HM and MM ranges.

### *Application: Pumps for froth (coal)*

Comments: Use vertical pump type VF.

*Recommendation:* VF.

### *Application: Pumps for coal/ water mixtures*

Comments: Use conventional pumps M ranges.

*Recommendation:* M ranges.

### *Application: Pumps for general purpose (coal)*

Comments: Coal industry normally does not use rubber pumps.

*Recommendation:* Use HM and MM.

## Industrial applications, waste & recycling

### Application: Pumps for effluent handling

Comments: Light-duty application. Use both horizontal and vertical pumps. Metal pumps is the first selection.

*Recommendation:* HM, MM and V ranges.

### Application: Hydraulic transportation of light waste

Comments: Use horizontal pumps with Vortex induced flow impellers.

*Recommendation:* HM and MM ranges.

### Application: Pumps for soil treatment

Comments: See minerals above. Pump type VT is recommended for mobile and semi-mobile plants (no leaking seal and easy to transport and install).

*Recommendation:* All ranges.

## Industrial applications, power & FGD

### Application: Pumps for FGD reactor feed (lime)

Comments: Normally the mineral applications use X, MD, H and M ranges, all with rubber and/or metal parts.

Rubber for high chloride concentrations.

*Recommendation:* MD, X, H and M ranges.

### Application: Pumps for FGD reactor discharge (gypsum)

Comments: See lime pumps above.

*Recommendation:* MD, X, H and M ranges

### Application: Bottom ash pumping

Comments: Metal pumps are preferred due to temperature and particle size.

Use horizontal pumps of type MD, X and H.

*Recommendation:* MDM, XM and HM ranges.

### Application: Fly ash pumping

Comments: Metal is normally used due to risk of oil contamination.

If rubber must be used (low pH) look out for any oil or other chemicals.

*Recommendation:* MD, X, H, M and VS ranges.

## Industrial applications, pulp & paper

### Application: Pumps for lime and caustic mud

*Comments:* These applications are normally of high temperature. Therefore metal parts are recommended.

*Recommendations:* HM and MM.

### Application: Pumps for reject pulp (containing sand)

*Comments:* Normally light duty, but metal parts are recommended. Normally we are competing with stainless steel pumps.

*Recommendation:* MM range.

### Application: Pumps for solids from debarking

*Comments:* For sand and bark we have developed an extra long vertical pump type VS.

Use metal parts and induced flow impeller (Vortex).

*Recommendation:* VS range.

### *Application: Pumps for hydraulic transportation of wood chips*

*Comments:* Use induced flow pumps (Vortex) of H and M type.

*Recommendation:* HM and MM ranges.

### *Application: Pumps for paper filler and coating slurries*

*Comments:* No rubber allowed due to colour contamination.

*Recommendation:* HM, MM, VS and VT ranges. (Only metal parts.)

### *Application: Floor spillage pumps*

*Comments:* Use a vertical pump of type VS. Sometimes stainless steel parts are required due to low pH.

*Recommendation:* VS range.

## *Industrial applications, metallurgy*

### *Application: Pumps for mill scale transportation*

*Comments:* First choice is vertical pump type VS with induced flow impeller and metallic parts.

Horizontal pumps use type HM with metal parts only

*Recommendation:* HM and VS ranges.

### *Application: Pumps for slag transportation*

*Comments:* Same considerations as for "Mill Scale" above.

### *Application: Pumps for wet scrubber effluents*

*Comments:* Normally we recommend pump of horizontal type M range or vertical pumps of VS range.

If pH is very low use rubber.

If pH is very low and temperature is very high use stainless steel parts or synthetic rubber.

*Recommendation:* MR and VS ranges.

### *Application: Pumps for iron powder transportation*

*Comments:* See dense media pumps above.

### *Application: Pumps for machine tool cuttings*

*Comments:* No rubber parts can be used due to oil.

Vertical pump of type VS and horizontal pumps type M.

*Recommendation:* VS and MM.

## *Industrial applications, chemical*

### *Application: Pumps for acid slurries*

*Comments:* First recommendation is horizontal pumps with rubber or stainless parts. For extremely abrasive slurries use horizontal pump type HR.

*Recommendation:* MR and HR ranges.

### *Application: Pumps for brines*

*Comments:* Very corrosive applications. Can also be abrasive (crystals).

Polyurethane can be used to avoid crystallization on pump parts.

*Recommendation:* HM, HR, MM, MR and VS (polyurethane parts).

### *Application: Pumps for caustics*

*Comments:* Both rubber and metal pumps can be used. Easy application.

*Recommendation:* MM, MR and VS ranges.

## *Industrial applications, mining*

### *Application: Pumps for hydraulic back filling (with or without cement)*

*Comments:* Watch out for deslimed tailings! Use horizontal pumps of type H or M with rubber or metal parts.

*Recommendation:* H and M ranges.

### *Application: Pumps for mine water (with solids)*

*Comments:* Normal recommendation is horizontal pumps type HM (multistage if required).

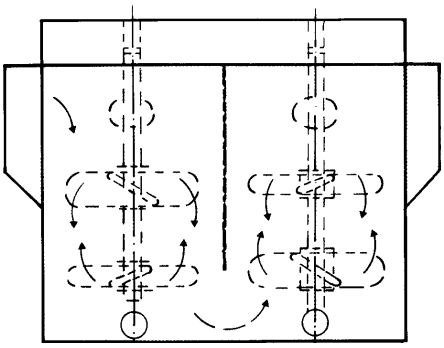
Watch out for corrosion!

*Recommendation:* HM.

## *Agitation – Attrition scrubber**

Attrition scrubbing is a bit more than storing and agitation of slurry. It is close to the processes of washing and separation.

Attrition scrubbers are simple, yet highly efficient, unit for scrubbing particles at slurry densities of 70-80% solids. Two opposed Helix impellers on each shaft create an intensive mixing action forcing individual particles against each other resulting in scrubbing, surface cleaning and disintegration of agglomerates.



### *Typical applications:*

Removal of Fe stains from sand particles. Disintegration of clay agglomerates in sand. Delamination of minerals such as Kaolin and Graphite. Blunging or slurryfying of dry clay prior to wet processing. Oil/Sand separation. Lime Slaking.

See data sheet on next page.

## *Attrition scrubber – Sizing*

Restriction: Maximum size of individual particle to scrubber is 10 mm.

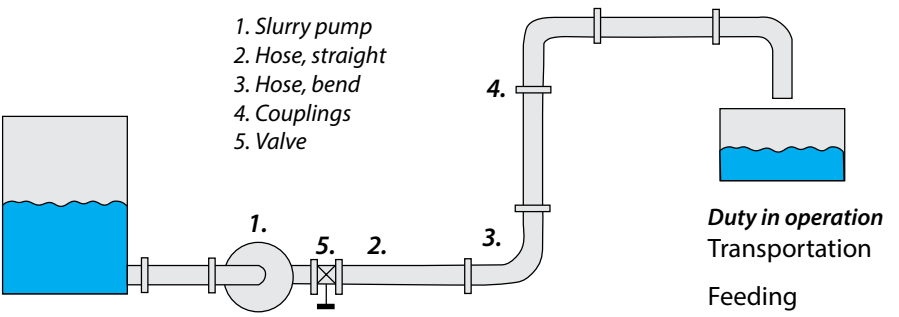
Due to the flow pattern an even number of cells must be selected (e.g. 2,4,6 cells). Base the retention time on test results or on an existing installation. In the absence of any other information assume a retention time of 6-8 minutes at 75% solids w/w for a typical sand scrubbing duty.

* Contact Metso for further information about this product.

## *"The slurry line"*

Slurry pumps are important being the energy source in all hydraulic systems for slurry handling. However, the slurry pumps are mainly just energy converters in the systems (converting electric energy to hydraulic flows). Equally important is to design "the slurry line" with the correct sizing of hoses (or pipes) including

- Hose layout geometry (vertical and horizontal) needed for the transportation job
- Hose material giving resistance to the wear and to the chemical environment
- Hose diameter enabling maximum efficiency of the slurry system




***Duty in operation***
Transportation

Feeding

***Slurry operations***
Grinding
Classification
Separation
Sedimentation
Mechanical dewatering



## *Slurry handling – Hoses*

Hoses are for slurry handling what conveyor belts are for dry materials handling. Simple products – which just have to maintain their functions. Otherwise the process flow will be interrupted and the up-time is gone.

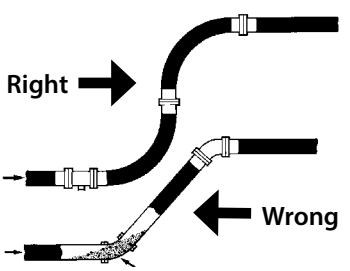
As most of the mineral process applications are continuous operations in an wearing environment, we will focus on rubber hosing in this section.

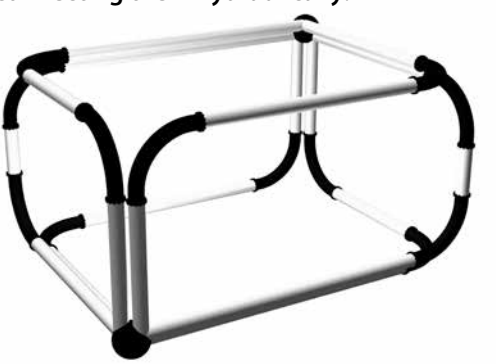
### *Slurry hose layout geometry*

There is just one rule for lay-outs of slurry hoses and pipes, but a golden one.

**" Never use sharp bends when connecting them hydraulically! "**

**Rule of thumb 1:**
Hose bend radius
> 3 x hose diameter



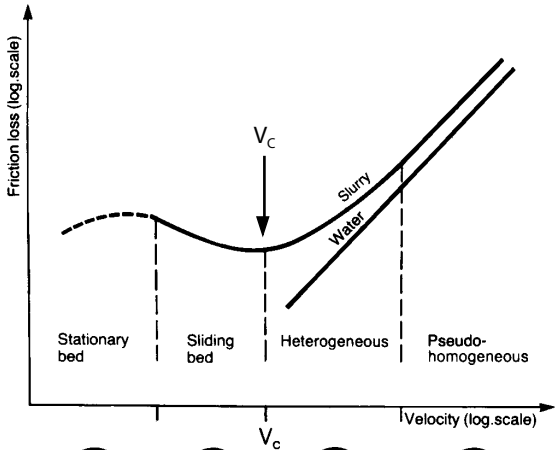



**Rule of thumb 2:**

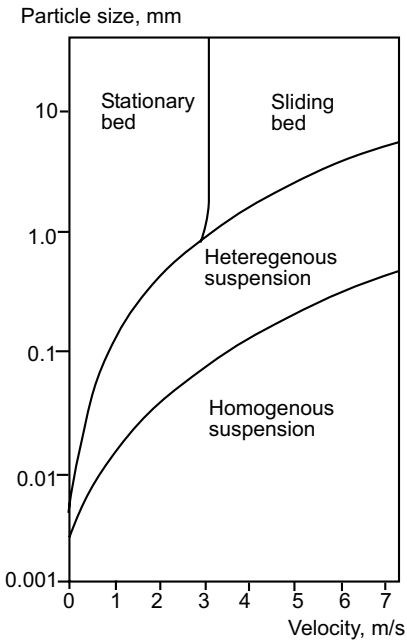
Going up – go vertically if you can!

## *Slurry hoses – diameter*

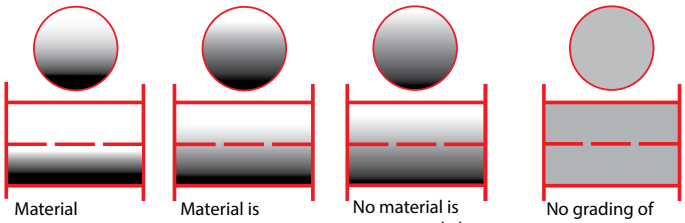
- Every slurry handling system needs proper hosing.
- Carrying velocity in the hose must exceed the settling velocity.
- Too high carrying velocity means increased power and wear.
- To balance the optimum slurry speed with the correct hose diameter is important.




*Vc = critical velocity = the velocity between sliding bed and heterogeneous flow conditions. Below this velocity particle clogging is at risk.*




*Flow conditions for sand (density= 2.7)*



Material movement is negligible. Particles bounce along the surface of the bed of material.

Material is transported along the bottom but a certain amount is in suspension.

No material is transported along the bottom.

No grading of concentration.

## *Typical Vc (hose i.d. 75 –150 mm, 3 – 6")*

| | |
|---|---|
| Flotation feed (80% passing 50 micron) | 1.0 m/s |
| Tailings (medium coarse) | 1.5-2.1 m/s |
| Sand fine | 2.4-3.0 m/s |
| Sand, medium | 3.4 m/s |
| Sand, coarse | 3.7-4.0 m/s |

### *Example:*

Flotation feed 120 $m^3$/h, $V_c$ = 1 m/s.
Select hose diameter.

120/3600 = 108 $m^3$/h, 0.03/1 = 0.03 $m^2$

$D^2$=0.03x4/3.14, D= 0.195 m = 195 mm

Hose inner diameter, see next page

Select diameter 204.

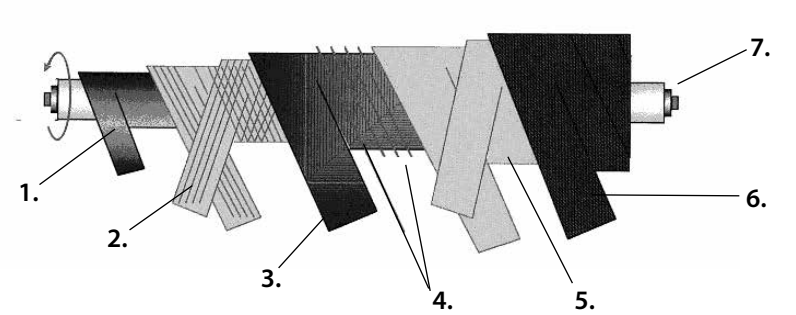
***Regarding wear in slurry lines, see 9:12!***

## *Slurry hose – material*

For most slurry applications polymer is first option (steel pipes not covered here). Reason is low weight, easy installation and long service life.

- If slurry temperature is high or aggressive chemicals are present use polyurethane lined pipes!
- In all other cases use rubber hoses

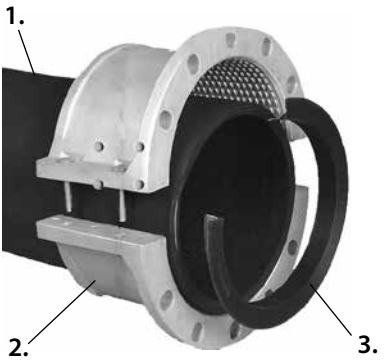
## *Slurry hose system – rubber*




### *Design*

1. Natural rubber (40 ShA)
2. Polyester cord
3. "Sandwich" rubber
4. Steel wire
5. Polyester cord
6. Outer cover
7. Production tool






- Long service life
- Simple installations
- 3 basic modules; 1) hose 2) couplings 3) gasket
- Lower cost (modular design)
- Tapered gasket for easier installation
- Easily configured
- Less vibration
- Lower noise level

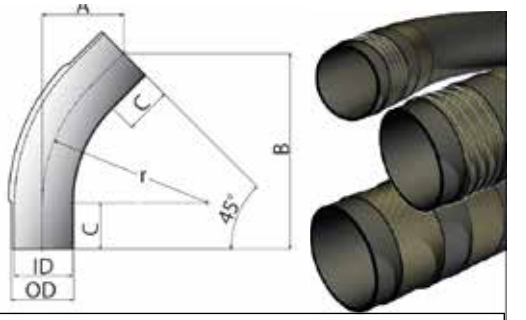
## *Material handling hoses*

| ID mm/inch | OD mm/inch | Standard length m/ft | Wear tube mm/inch | Working pressure MPa/psi | Min.bend radius mm/inch | Slurry hose kg/m / lbs/ft |
|---|---|---|---|---|---|---|
| 51/2 | 72/3 | 20/66 | 6 / 1/4 | 1.0/150 | 300/12 | 2.4/1.6 |
| 76/3 | 99.5/4 | 20/66 | 6 / 1/4 | 1.0/150 | 450/18 | 4.1/2.8 |
| 102 4 | 125/5 | 20/66 | 6 / 1/4 | 1.0/150 | 600/24 | 5.4/3.7 |
| 127/5 | 154/6 | 20/66 | 6 / 1/4 | 1.0/150 | 750/30 | 7.5/5.1 |
| 152/6 | 178/7 | 10/33 | 6 / 1/4 | 1.0/150 | 900/35 | 8.9/6.1 |
| 204/8 | 238/9 | 10/33 | 7.5 / 5/16 | 1.0/150 | 1300/51 | 16.2/11.0 |
| 254/10 | 291/11 | 10/33 | 7.5 / 5/16 | 0.5/75 | 1600/63 | 21.3/14.5 |
| 305/12 | 341/13 | 10/33 | 7.5 / 5/16 | 0.5/75 | 1800/71 | 26.5/18.0 |
| 355/14 | 403/16 | 10/33 | 12 / 1/2 | 0.5/75 | 2200/87 | 40.8/27.7 |
| 405/16 | 456/18 | 10/33 | 12 / 1/2 | 0.5/75 | 2500/98 | 46.3/31.5 |
| 457/18 | 507/20 | 10/33 | 10.5 / 1/2 | 0.5/75 | 2900/114 | 55.2/37.5 |
| 508/20 | 558/22 | 10/33 | 12 / 1/2 | 0.5/75 | 3100/122 | 64.4/43.8 |
| 610/24 | 664/26 | 10/33 | 12 / 1/2 | 0.5/75 | 3700/146 | 87.7/59.6 |

## *Rubber lined steel pipes*

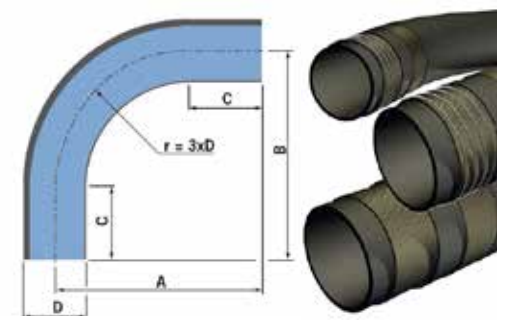
| ID mm/inch | Lenght m/feet | Wear tube mm/inch | Operating pressure MPa/psi | Weight incl. kg/lbs |
|---|---|---|---|---|
| 102/4 | 3/10 | 5/0.2 | 1.0/150 | 22/49 |
| 102/4 | 6/20 | 5/0.2 | 1.0/150 | 44/96 |
| 102/4 | 10/33 | 5/0.2 | 1.0/150 | 72/160 |
| 127/5 | 3/10 | 5/0.2 | 1.0/150 | 28/63 |
| 127/5 | 6/20 | 5/0.2 | 1.0/150 | 56/123 |
| 127/5 | 10/33 | 5/0.2 | 1.0/150 | 93/204 |
| 152/6 | 3/10 | 5/0.2 | 1.0/150 | 34/75 |
| 152/6 | 6/20 | 5/0.2 | 1.0/150 | 67/149 |
| 152/6 | 10/33 | 5/0.2 | 1.0/150 | 112/247 |
| 204/8 | 3/10 | 5/0.2 | 1.0/150 | 61/134 |
| 204/8 | 6/20 | 5/0.2 | 1.0/50 | 119/261 |
| 204/8 | 10/33 | 5/0.2 | 1.0/150 | 196/431 |
| 254/10 | 3/10 | 5/0.2 | 0.5/75 | 75/165 |
| 254/10 | 6/20 | 5/0.2 | 0.5/75 | 147/324 |
| 254/10 | 10/33 | 5/0.2 | 0.5/75 | 243/536 |
| 305/12 | 3/10 | 5/0.2 | 0.5/75 | 89/196 |
| 305/12 | 6/20 | 5/0.2 | 0.5/75 | 175/386 |
| 305/12 | 10/33 | 5/0.2 | 0.5/75 | 290/639 |
| 355/14 | 3/10 | 10/0.4 | 0.5/75 | 162/356 |
| 355/14 | 6/20 | 10/0.4 | 0.5/75 | 320/704 |
| 355/14 | 10/33 | 10/0.4 | 0.5/75 | 530/1169 |
| 405/16 | 3/10 | 10/0.4 | 0.5/75 | 185/408 |
| 405/16 | 6/20 | 10/0.4 | 0.5/75 | 364/803 |
| 405/16 | 10/33 | 10/0.4 | 0.5/75 | 603/1329 |
| 457/18 | 3/10 | 10/0.4 | 0.5/75 | 208/458 |
| 457/18 | 6/20 | 10/0.4 | 0.5/75 | 409/901 |
| 457/18 | 10/33 | 10/0.4 | 0.5/75 | 676/1491 |
| 508/20 | 3/10 | 10/0.4 | 0.5/75 | 233/514 |
| 508/20 | 6/20 | 10/0.4 | 0.5/75 | 456/1004 |
| 508/20 | 10/33 | 10/0.4 | 0.5/75 | 752/1658 |
| 610/24 | 3/10 | 10/0.4 | 0.5/75 | 286/630 |
| 610/24 | 6/20 | 10/0.4 | 0.5/75 | 551/1214 |
| 610/24 | 10/33 | 10/0.4 | 0.5/75 | 904/1993 |

## *3xD bends 45º*



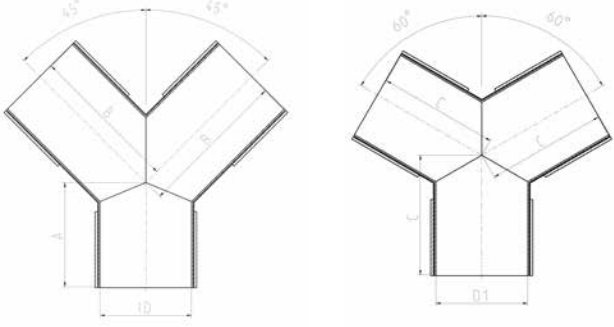

| ID mm/inch | OD mm/inch | Wear tube outer radius mm/inch | Operating pressure MPa/psi | A x B mm/inch | C mm/inch | r |
|---|---|---|---|---|---|---|
| 51/2 | 72/3 | 8 / 5/16 | 1/150 | 120 x 290/5x11 | 105/4 | 155 |
| 76/3 | 99.5/4 | 8 / 5/16 | 1/150 | 140 x 340/6x13 | 105/4 | 230 |
| 102/4 | 125/5 | 8 / 5/16 | 1/150 | 195 x 475/8x19 | 150/6 | 305 |
| 127/5 | 154/6 | 8 / 5/16 | 1/150 | 245 x 595/10x23 | 190/7 | 380 |
| 152/6 | 178/7 | 8 / 5/16 | 1/150 | 285 x 690/11x27 | 215/8 | 455 |
| 204/8 | 238/9 | 10 / 7/16 | 1/150 | 375 x 905/15x36 | 275/11 | 615 |
| 254/10 | 291/11 | 10 / 7/16 | 0.5/75 | 375 x 905/15x36 | 215/8 | 765 |
| 305/12 | 341/13 | 10 / 7/16 | 0.5/75 | 445 x 1085/18x43 | 255/10 | 915 |
| 355/14 | 403/16 | 16 / 5/8 | 0.5/75 | 520 x 1255/20x49 | 295/12 | 1065 |
| 405/16 | 456/18 | 16 / 5/8 | 0.5/75 | 640 x 1540/25x61 | 400/16 | 1215 |
| 457/18 | 507/20 | 14 / 9/16 | 0.5/75 | 755 x 1825/30x72 | 500/20 | 1371 |
| 508/20 | 558/22 | 16 / 5/8 | 0.5/75 | 800 x 1930/31x76 | 500/20 | 1520 |
| 610/24 | 664/26 | 16 / 5/8 | 0.5/75 | 965 x 2352/38x93 | 605/24 | 1830 |

## *3xD bends 90º*



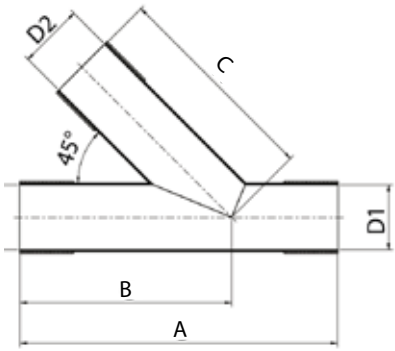

| ID mm/inch | OD mm/inch | Wear tube outer radius mm/inch | Operating pressure MPa/psi | A x B mm/inch | C mm/inch | r |
|---|---|---|---|---|---|---|
| 51/2 | 72/3 | 8 / 5/16 | 1/150 | 260 x 260/10x10 | 105/4 | 155 |
| 76/3 | 99.5/4 | 8 / 5/16 | 1/150 | 335 x 335/13x13 | 105/4 | 230 |
| 102/4 | 125/5 | 8 / 5/16 | 1/150 | 455 x 455/18x18 | 150/6 | 305 |
| 127/5 | 154/6 | 8 / 5/16 | 1/150 | 570 x 570/22x22 | 190/7 | 380 |
| 152/6 | 178/7 | 8 / 5/16 | 1/150 | 670 x 670/26x26 | 215/8 | 455 |
| 204/8 | 238/9 | 10 / 7/16 | 1/150 | 890 x 890/35x35 | 275/11 | 615 |
| 254/10 | 291/11 | 10 / 7/16 | 0.5/75 | 980 x 980/39x39 | 215/8 | 765 |
| 305/12 | 341/13 | 10 / 7/16 | 0.5/75 | 1170 x 1170/46x46 | 255/10 | 915 |
| 355/14 | 403/16 | 16 / 5/8 | 0.5/75 | 1360 x 1360/54x54 | 295/12 | 1065 |
| 405/16 | 456/18 | 16 / 5/8 | 0.5/75 | 1615 x 1615/64x64 | 400/16 | 1215 |
| 457/18 | 507/20 | 14 / 9/16 | 0.5/75 | 1871 x 1871/74x74 | 500/20 | 1371 |
| 508/20 | 558/22 | 16 / 5/8 | 0.5/75 | 2020 x 2020/80x80 | 500/20 | 1520 |
| 610/24 | 664/26 | 16 / 5/8 | 0.5/75 | 2440 x 2440/96x96 | 605/24 | 1830 |

## *Branch pipes*



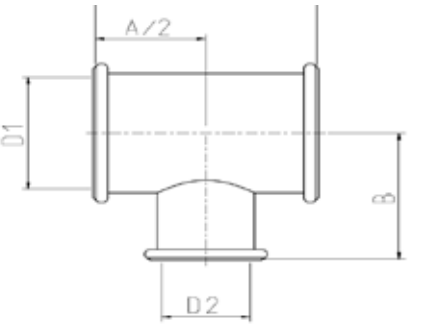
| ID<br>mm/inch | A<br>mm/inch | B<br>mm/inch | C<br>mm/inch | Wear tube<br>mm/inch | Operating pressure<br>MPa/psi |
|---|---|---|---|---|---|
| 102/4 | 200/8 | 300/12 | 250/10 | 5/0.2 | 1.0/150 |
| 127/5 | 250/10 | 350/14 | 300/12 | 5/0.2 | 1.0/150 |
| 152/6 | 300/12 | 400/16 | 300/12 | 5/0.2 | 1.0/150 |
| 204/8 | 350/14 | 450/18 | 400/20 | 5/0.2 | 1.0/150 |
| 254/10 | 300/16 | 450/18 | 350/14 | 5/0.2 | 0.5/75 |
| 305/12 | 350/14 | 500/20 | 400/16 | 5/0.2 | 0.5/75 |
| 355/14 | 400/16 | 600/24 | 450/18 | 10/0.4 | 0.5/75 |
| 405/16 | 550/22 | 750/30 | 600/24 | 10/0.4 | 0.5/75 |
| 457/18 | 650/26 | 850/33 | 700/28 | 10/0.4 | 0.5/75 |
| 508/20 | 700/28 | 900/35 | 750/30 | 10/0.4 | 0.5/75 |
| 610/24 | 850/33 | 1050/41 | 900/35 | 10/0.4 | 0.5/75 |

## *Branch pipes*




| ID D1<br>mm/inch | ID D2<br>mm/inch | A<br>mm/inch | B<br>mm/inch | C<br>mm/inch | Wear tube<br>mm/inch | Operating pressure<br>MPa/psi |
|---|---|---|---|---|---|---|
| 102/4 | 102/4 | 700/28 | 500/20 | 400/16 | 5/0.2 | 1.0/150 |
| 127/5 | 127/5 | 800/31 | 550/22 | 450/18 | 5/0.2 | 1.0/150 |
| 152/6 | 152/6 | 900/35 | 625/25 | 550/22 | 5/0.2 | 1.0/150 |
| 204/8 | 204/8 | 1100/43 | 750/30 | 650/26 | 5/0.2 | 1.0/150 |
| 254/10 | 254/10 | 1100/43 | 800/31 | 700/28 | 5/0.2 | 0.5/75 |
| 305/12 | 305/12 | 1300/51 | 950/37 | 800/31 | 5/0.2 | 0.5/75 |
| 355/14 | 355/14 | 1500/59 | 1100/43 | 950/37 | 10/0.4 | 0.5/75 |
| 405/16 | 405/16 | 1900/75 | 1350/53 | 1150/45 | 10/0.4 | 0.5/75 |
| 457/18 | 457/18 | 2000/79 | 1400/55 | 1300/51 | 10/0.4 | 0.5/75 |
| 508/20 | 508/20 | 2350/93 | 1650/65 | 1450/57 | 10/0.4 | 0.5/75 |
| 610/24 | 610/24 | 2750/108 | 1950/77 | 1750/69 | 10/0.4 | 0.5/75 |

## *Branch pipes*



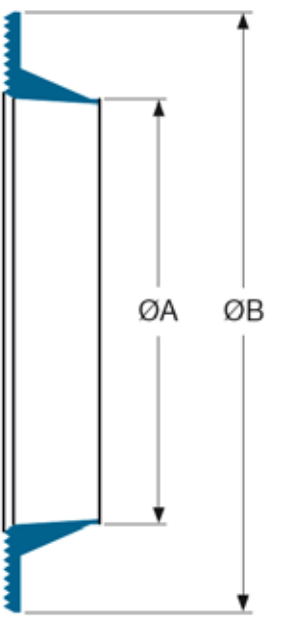

With split steel flanges

| ID D1 mm/inch | ID D2 mm/inch | A mm/inch | B mm/inch | Wear tube mm/inch | Operating pressure MPa/psi |
|---|---|---|---|---|---|
| 102/4 | 102/4 | 380/15 | 258/10 | 5/0.2 | 1.0/150 |
| 127/5 | 102/4 | 380/15 | 271/10.5 | 5/0.2 | 1.0/150 |
| 152/6 | 102/4 | 380/15 | 283/11 | 5/0.2 | 1.0/150 |
| 204/8 | 102/4 | 380/15 | 310/12 | 5/0.2 | 1.0/150 |
| 254/10 | 102/4 | 380/15 | 335/13 | 5/0.2 | 0.5/75 |
| 305/12 | 102/4 | 380/15 | 361/14 | 5/0.2 | 0.5/75 |
| 35514 | 102/4 | 380/15 | 392/15 | 10/0.4 | 0.5/75 |
| 405/16 | 152/6 | 380/15 | 417/16 | 10 /0.4 | 0.5/75 |
| 457/18 | 152/6 | 380/15 | 443/17 | 10/0.4 | 0.5/75 |
| 508/20 | 152/6 | 380/15 | 469/18 | 10/0.4 | 0.5/75 |
| 610/24 | 152/6 | 380/15 | 520/20 | 10/0.4 | 0.5/75 |

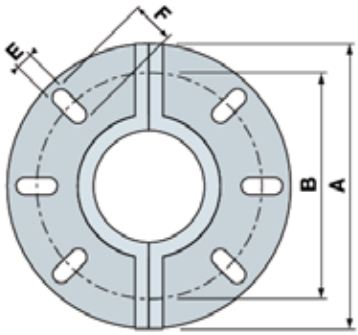


## *Gaskets*

| For internal hose diameter mm/inch | A mm/inch | B mm/inch |
|---|---|---|
| 51/2.0 | 49/1.9 | 89/3.5 |
| 76/3.0 | 74/2.9 | 118/4.6 |
| 102/4.0 | 98/3.9 | 144/5.7 |
| 127/5.0 | 123/4.9 | 175/6.9 |
| 152/6.0 | 148/5.8 | 202/8.0 |
| 204/8.0 | 198/7.8 | 258/10.0 |
| 254/10.0 | 248/9.7 | 314/12.3 |
| 305/12.0 | 298/11.7 | 365/14.3 |
| 355/14.0 | 350/13.7 | 415/16.3 |
| 405/16.0 | 400/15.7 | 466/18.3 |
| 457/18.0 | 452/17.8 | 520/20.5 |
| 508/20.0 | 503/19.8 | 578/22.7 |
| 610/24.0 | 605/23.8 | 684/27.0 |



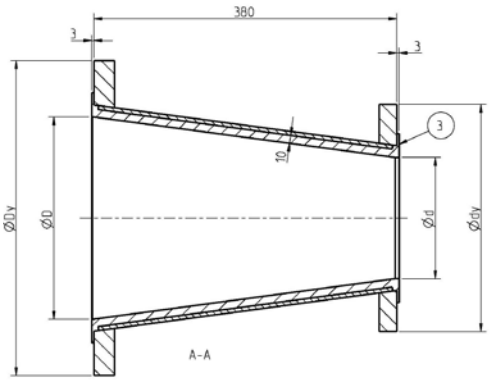
## *Couplings*



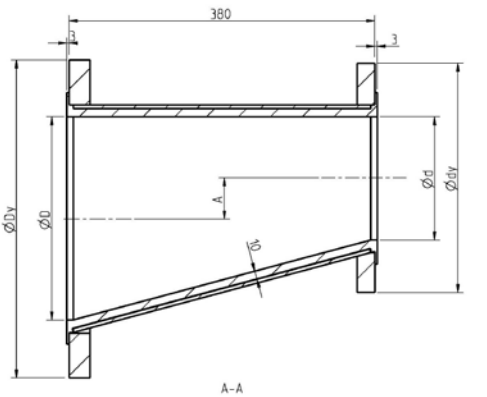
| Coupl. size | A mm/inch | B mm/inch | C mm/inch | ExF mm/inch | Holes per joint | Sect./ segment |
|---|---|---|---|---|---|---|
| 51 | 165/7 | 124/5 | 91/3.5 | 18x20/ 0.7x0.8 | 2 | 2 |
| 76 | 200/8 | 158/6 | 91/3.5 | 18x24/0.7x0.9 | 2 | 2 |
| 102 | 220/9 | 184/7 | 133/5 | 18x24/0.7x0.9 | 3 | 2 |
| 127 | 250/10 | 213/ 8 | 165/6.5 | 23x26/0.9x 1.0 | 3 | 2 |
| 152 | 285/11 | 238/9 | 197/8 | 23x27/0.9x1.0 | 3 | 2 |
| 204 | 340/13 | 295/12 | 257/10 | 23x26/0.9x1.0 | 3 | 2 |
| 254 | 405/16 | 353/14 | 197/8 | 25x33/1.0x1.3 | 5 | 2 |
| 305 | 476/19 | 401/16 | 237/9 | 25x30/1.0x1.2 | 5 | 2 |
| 1305 | 495/19.5 | 424/17 | 237/9 | 25x40/1.0x1.5 | 5 | 2 |
| 355 | 530/21 | 455/18 | 277/9 | 27x40/1.0x1.5 | 3 | 4 |
| 1355 | 530/21 | 466/18.5 | 277/9 | 28x41/1.1x1.6 | 2 | 4 |
| 405 | 600/24 | 521/21 | 400/16 | 27x51/1.0x2.0 | 3 | 4 |
| 457 | 634/25 | 556/22 | 450/18 | 27x36/1.0x1.4 | 4 | 4 |
| 1457 | 634/25 | 569/22.5 | 450/18 | 27x36/1.0x1.4 | 3 | 4 |
| 508 | 698/27 | 621/24 | 500/20 | 27x44/1.0x1.7 | 4 | 4 |
| 610 | 820/32 | 731/29 | 600/24 | 30x52/1.0x2.0 | 4 | 4 |

| Coupl. Size | Weight kg/lbs | Matches flange DIN 2501 PN 10 | Matches flange Ansi B16.1, 150 lbs mm/inch | Operating press. Mpa/psi |
|---|---|---|---|---|
| 51 | 1.8/4 | 50 | 51/2″ | 1.0/145 |
| 76 | 2.4/5 | 80 | 76/3″ | 1.0/ 145 |
| 102 | 3.5/8 | 100 | 102/4″ | 1.0/ 145 |
| 127 | 4.8/11 | 125 | 127/5″ | 1.0/ 145 |
| 152 | 6.2/14 | 150 | 152/6″ | 1.0/ 145 |
| 204 | 10.6/23 | 200 | 204/8″ | 1.0/ 145 |
| 254 | 11.1/24 | 250 | 254/10″ | 0.5/73 |
| 305 | 18.4/41 | 300 | - | 0.5/ 73 |
| 1305 | 21.4/47 | - | 305/12″ | 0.5/ 73 |
| 355 | 25.6/56 | 350 | - | 0.5/ 73 |
| 1355 | 27.0/60 | - | 355/14″ | 0.5/ 73 |
| 405 | 45.4/100 | 400 | 406/16″ | 0.5/ 73 |
| 457 | 49.9/110 | 450 | - | 0.5/ 73 |
| 1457 | 51.3/113 | - | 457/18″ | 0.5/ 73 |
| 508 | 61.7/136 | 500 | 508 /20″ | 0.5/ 73 |
| 610 | 79.5/175 | 600 | 610/24″ | 0.5/ 73 |

## *Reducers, rubber lined steel*




Concentric



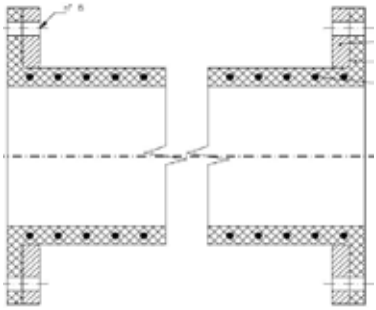

Eccentric

| ϕD/ϕd mm-inch | Wear tube mm/inch | Working pressure Mpa/psi | Length mm/inch |
|---|---|---|---|
| 127/102-5/4 | 10/0.4 | 1.0/145 | 380/15 |
| 152/102-6/4 | 10/0.4 | 1.0/145 | 380/15 |
| 152/127-6/5 | 10/0.4 | 1.0/145 | 380/15 |
| 204/127-8/5 | 10/0.4 | 1.0/145 | 380/15 |
| 204/152-8/6 | 10/0.4 | 1.0/145 | 380/15 |
| 254/152-10/6 | 10/0.4 | 1.0/145 | 380/15 |
| 254/204-10/8 | 10/0.4 | 1.0/145 | 380/15 |
| 305/204-12/8 | 10/0.4 | 1.0/145 | 380/15 |
| 305/254-12/10 | 10/0.4 | 1.0/145 | 380/15 |
| 355/254-14/10 | 10/0.4 | 1.0/145 | 380/15 |
| 355/305-14/12 | 10/0.4 | 1.0/145 | 380/15 |
| 405/305-16/12 | 10/0.4 | 1.0/145 | 380/15 |
| 405/355-16/14 | 10/0.4 | 1.0/145 | 380/15 |
| 457/355-19/14 | 10/0.4 | 1.0/145 | 380/15 |
| 457/405-19/16 | 10/0.4 | 1.0/145 | 380/15 |
| 508/405-20/16 | 10/0.4 | 1.0/145 | 380/15 |
| 610/508-24/20 | 10/0.4 | 1.0/145 | 380/15 |

Flange drilling according DIN 2501 PN10 or ANSI B16.5 150lbs

## *Compensators*

With split steel flanges



| ID mm/inch | Length mm/inch | Permissible movement, mm/inch Com-pression | Elon-gation | Lateral | Angular | Operating pressure MPa/psi | Weight inc. Flanges kg/lbs |
|---|---|---|---|---|---|---|---|
| 51/2″ | 200/8 | 2/0.07 | 2/0.07 | 5/0.20 | 3° | 1.0/150 | 4,3/9.5 |
| 76/3″ | 200/8 | 2/0.07 | 2/0.07 | 5/0.20 | 3° | 1.0/150 | 4,3/9.5 |
| 102/4″ | 200/8 | 2/0.07 | 2/0.07 | 5/0.20 | 3° | 1.0/150 | 4,3/9.5 |
| 127/5″ | 200/8 | 2/0.07 | 2/0.07 | 10/0.40 | 3° | 1.0/150 | 5,8/12.8 |
| 152/6″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 7,3/16.1 |
| 201/8″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 10,0/22.0 |
| 254/10″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 13,9/30.6 |
| 305/12″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 16,0/35.3 |
| 355/14″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 20,9/46.1 |
| 405/16″ | 250/10 | 2,5/0.09 | 2,5/0.09 | 10/0.40 | 3° | 1.0/150 | 29,3/64.6 |
| 457/18″ | 300/12 | 3/0.11 | 3/0.11 | 10/0.40 | 3° | 1.0/150 | 33,7/74.3 |
| 508/20″ | 300/12 | 3/0.11 | 3/0.11 | 10/0.40 | 3° | 1.0/150 | 42,8/94.4 |
| 610/24″ | 300/12 | 3/0.11 | 3/0.11 | 10/0.40 | 3° | 1.0/150 | 56,0/123.5 |

Flange drilling according DIN 2501 PN10 or ANSI B16.5 150lbs



## *Tailing compensators / bends*

With split steel flanges

| ID mm/inch | Length mm/inch | Permissible movement, mm/inch Com-pression | Elon-gation | Dis-placement | Bending radius | Operating pressure MPa/psi | Weight inc. Flanges kg/lbs |
|---|---|---|---|---|---|---|---|
| 204/8″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 1020/40 | 2.5/285 | 35/77 |
| 204/8″ | 5000/197 | 250/10 | 250/10 | 300/12 | 1020/40 | 2.5/285 | 115/254 |
| 254/10″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 1270/50 | 2.5/285 | 51/112 |
| 254/10″ | 5000/197 | 250/10 | 250/10 | 300/12 | 1270/50 | 2.5/285 | 177/390 |
| 305/12″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 1525/60 | 2.5/285 | 67/148 |
| 305/12″ | 5000/197 | 250/10 | 250/10 | 300/12 | 1525/60 | 2.5/285 | 222/488 |
| 355/14″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 1775/70 | 1.6/230 | 79/174 |
| 355/14″ | 5000/197 | 250/10 | 250/10 | 300/12 | 1775/70 | 1.6/230 | 295/650 |
| 405/16″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 2025/80 | 1.6/230 | 99/218 |
| 405/16″ | 5000/197 | 250/10 | 250/10 | 300/12 | 2025/80 | 1.6/230 | 343/756 |
| 457/18″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 2285/90 | 1.6/230 | 118/260 |
| 457/18″ | 5000/197 | 250/10 | 250/10 | 300/12 | 2285/90 | 1.6/230 | 411/907 |
| 508/20″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 2540/100 | 1.6/230 | 157/346 |
| 508/20″ | 5000/197 | 250/10 | 250/10 | 300/12 | 2540/100 | 1.6/230 | 504/1112 |
| 610/24″ | 500/20 | 25/1 | 25/1 | 30/1.2 | 3050/120 | 1.6/230 | 225/496 |
| 610/24″ | 6000/236 | 250/10 | 250/10 | 300/12 | 3050/120 | 1.6/230 | 794/1750 |

Flange drilling according DIN 2501 PN16/PN25 or ANSI B16.5 150/300lbs

## *Tailing pipes*

With split steel flanges

| Length m/ft | Wear tube mm/inch | Operating pressure Mpa/psi | Weight incl. flanges kg/lbs |
|---|---|---|---|
| 3/10 | 5/0.2 | 2.5/285 | 79/174 |
| 6/20 | 5/0.2 | 2.5/285 | 137/301 |
| 10/33 | 5/0.2 | 2.5/285 | 214/471 |
| 3/10 | 5/0.2 | 2.5/285 | 103/226 |
| 6/20 | 5/0.2 | 2.5/285 | 175/386 |
| 10/33 | 5/0.2 | 2.5/285 | 271/598 |
| 3/10 | 5/0.2 | 2.5/3285 | 125/276 |
| 6/20 | 5/0.2 | 2.5/285 | 211/465 |
| 10/33 | 5/0.2 | 2.5/285 | 326/718 |
| 3/10 | 10/0.4 | 1.6/230 | 212/466 |
| 6/20 | 10/0.4 | 1.6/230 | 370/815 |
| 10/33 | 10/0.4 | 1.6/230 | 610/1345 |
| 3/10 | 10/0.4 | 1.6/230 | 250/551 |
| 6/20 | 10/0.4 | 1.6/230 | 429/946 |
| 10/33 | 10/0.4 | 1.6/230 | 668/1472 |
| 3/10 | 10/0.4 | 1.6/230 | 288/634 |
| 6/20 | 10/0.4 | 1.6/230 | 489/1077 |
| 10/33 | 10/0.4 | 1.6/230 | 756/1667 |
| 3/10 | 10/0.4 | 1.6/230 | 351/775 |
| 6/20 | 10/0.4 | 1.6/230 | 574/1264 |
| 10/33 | 10/0.4 | 1.6/230 | 870/1918 |
| 3/10 | 10/0.4 | 1.6/230 | 466/1027 |
| 6/20 | 10/0.4 | 1.6/230 | 731/1611 |
| 10/33 | 10/0.4 | 1.6/230 | 1084/2390 |

Flange drilling according DIN 2501 PN16/PN25 or ANSI B16.5 150/300lbs

## *Introduction*

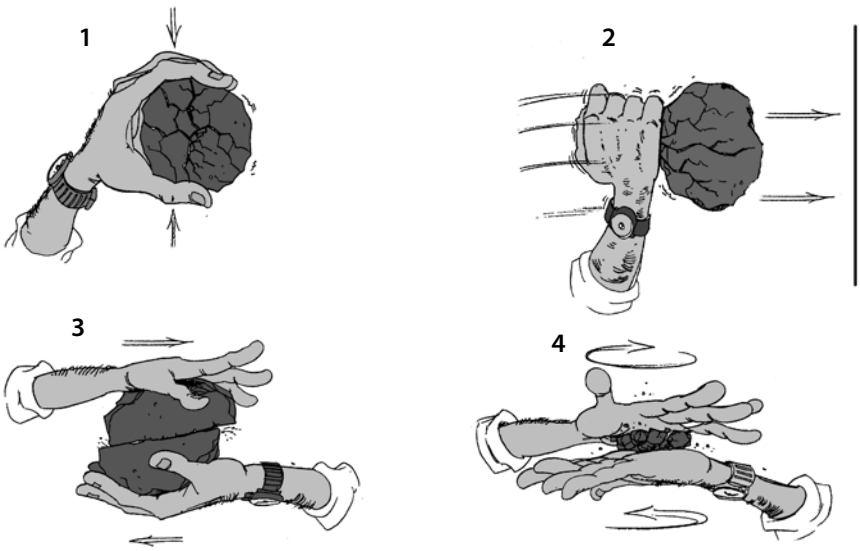
Mineral processing activities unavoidably result in wear. And wear costs money. Often lots of money. This is related to the structure of rock, ore or minerals, being crystals normally both hard and abrasive.

### *Why wear at all?*

Wear is caused by the normal rock stress forces

- Compression (1)
- Impaction (2)
- Shearing (3)
- Attrition (4)

in combination with **mineral abrasion, hardness and energy!**




## *Wear in operation*

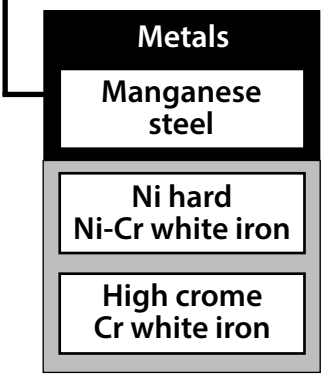


***caused by***

| COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING |
|---|---|---|---|

| METALS | protected by | Polymers |
|---|---|---|
| Manganese steel | | Rubber |
| Cr-MO steel | | Polyurethane |
| High crome Cr white iron | | CERAMICS |
| Ni hard Ni-Cr white iron | | |

## *Wear by compression*




**Applications:**

**Crushers** { **Gyratory**, **Cone**, **Jaw**

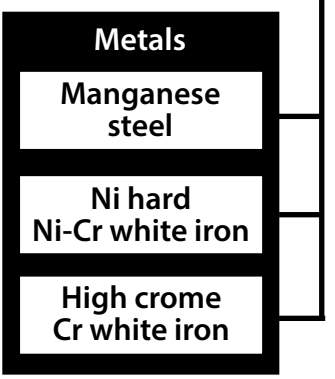
**Metals and compression**

**Manganese steel:** The first option for compression wear is manganese steel. This alloy has a very special property, being self hardening and self healing when exposed to large amounts of compression and impact energy.
Normal standard is a 14% Mn alloy which is first option in most crushing applications.
18 % Mn alloy is a harder but also a more brittle alloy used in applications where the rock is softer (limited self hardening) but very abrasive.

***Restrictions:***
*When installed in applications without work hardening service life will be poor!*

The alloys of cast "white iron" type (High-chrome and Ni-hard) shall be avoided in crushers submitted to heavy compression.

## *Wear by impaction (high)*




**Applications:**

**Impactors** { **HSI**, **VSI**

**Grinding mills**

**Slurry pumps**

**Metals and impaction**

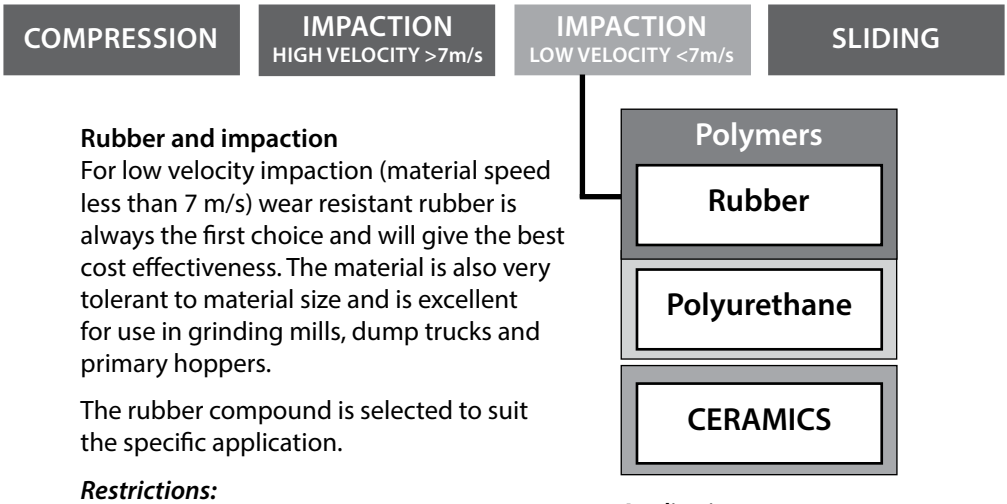
The metals can be classified as:

**Manganese:** Needs high impaction for self hardening. If impaction is getting lower and sliding is increasing Manganese is not suitable.
**High Chrome:** Opposite to manganese, can take heavy sliding but is more fragile and therefore limited against impaction.
**Ni-hard:** Somewhere between the two materials above.
**Cr-Mo:** Used in grinding when High Chrome is too brittle

***Note!*** *The use of chrome steel (less brittle than chrome iron) is increasing for liners, curtains and hammers.*

**Poly-Met:** A combination of rubber and wear resistant metallic alloys is often an alternative to an all metallic lining in high impact grinding mills as the rubber will absorb the impact and prevent cracking of the metal.

## *Wear by impaction (low)*



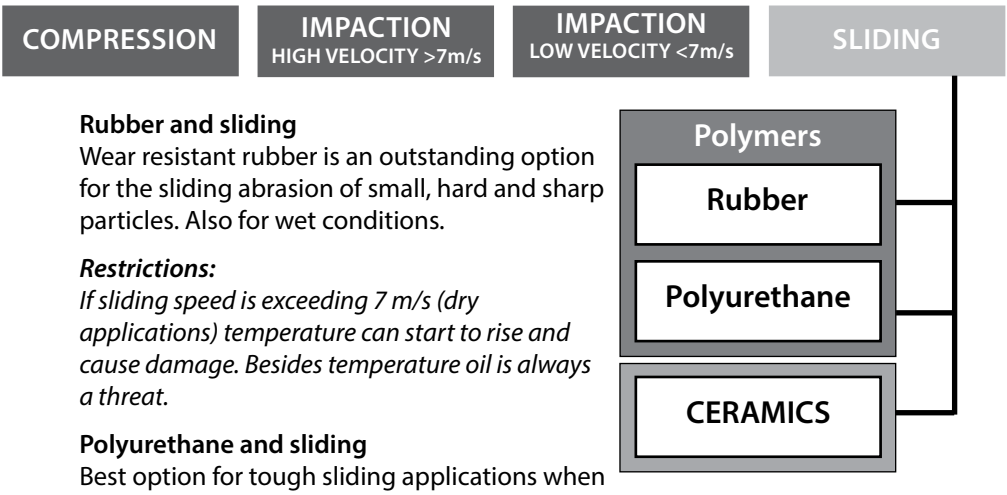

**Rubber and impaction**
For low velocity impaction (material speed less than 7 m/s) wear resistant rubber is always the first choice and will give the best cost effectiveness. The material is also very tolerant to material size and is excellent for use in grinding mills, dump trucks and primary hoppers.

The rubber compound is selected to suit the specific application.

***Restrictions:***
*Look out for aromatic and fuel oils.*
*Impact angles have to be considered, see 9:4.*

**Applications:**
**Dump Trucks, Feeder hoppers, Transfer points, Grinding Mills Slurry pumps**

## *Wear by sliding*




**Rubber and sliding**
Wear resistant rubber is an outstanding option for the sliding abrasion of small, hard and sharp particles. Also for wet conditions.

***Restrictions:***
*If sliding speed is exceeding 7 m/s (dry applications) temperature can start to rise and cause damage. Besides temperature oil is always a threat.*

**Polyurethane and sliding**
Best option for tough sliding applications when particle size is lower than 50 mm. Excellent in wet applications. Tolerant to chemicals and oil.

**Applications:**
**Chutes, Spouts**

***Restrictions:***
*Large sizes and high velocity might cause problems.*

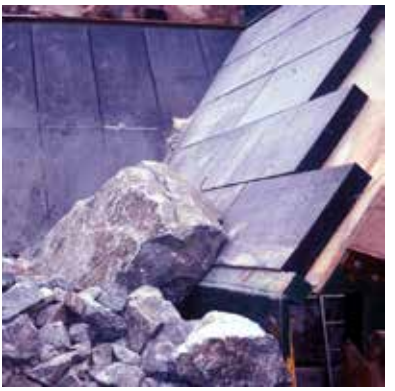
**Ceramics and sliding**
The natural choice when mission is too hard for the options above. Hardness, resistance to temperature and corrosion plus low weight gives a masterpiece for sliding.
$Al_2O_3$ (Aluminum oxide) is the most cost-effective material.

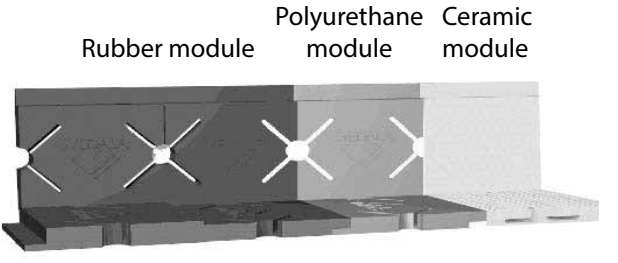
***Restrictions:***
*Impaction is dangerous for ceramics (cracking) and must be avoided. Combination ceramics + rubber is an option. Composition and quality can vary from supplier to supplier.*

# Wear protection – Wear products

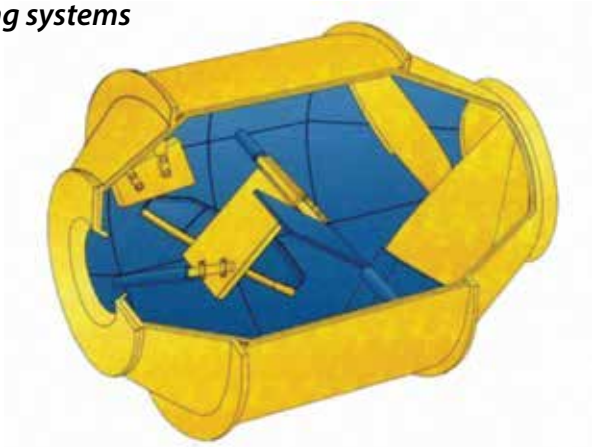
## Modules

Sheets, elements and profiles

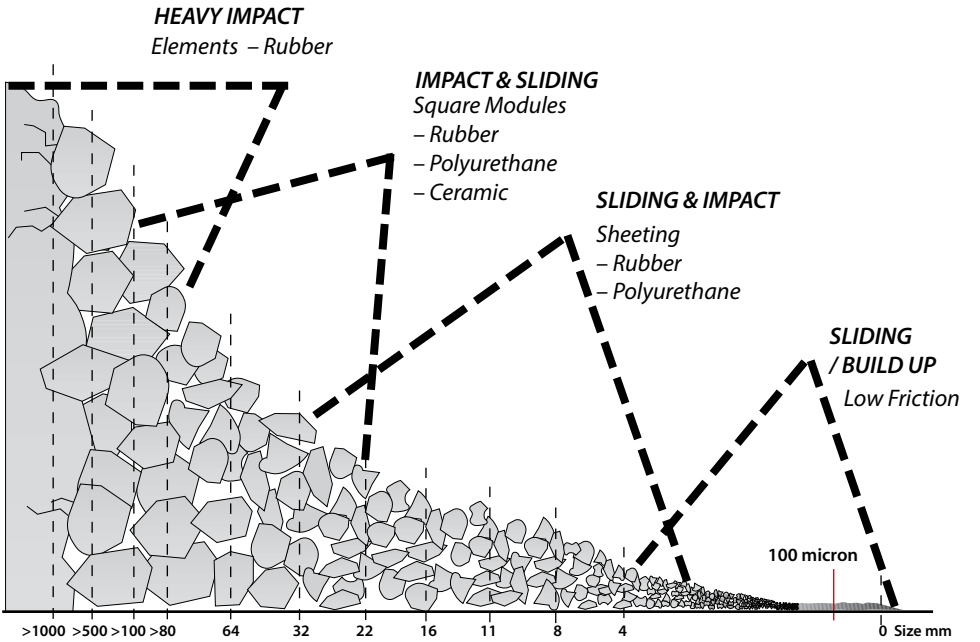




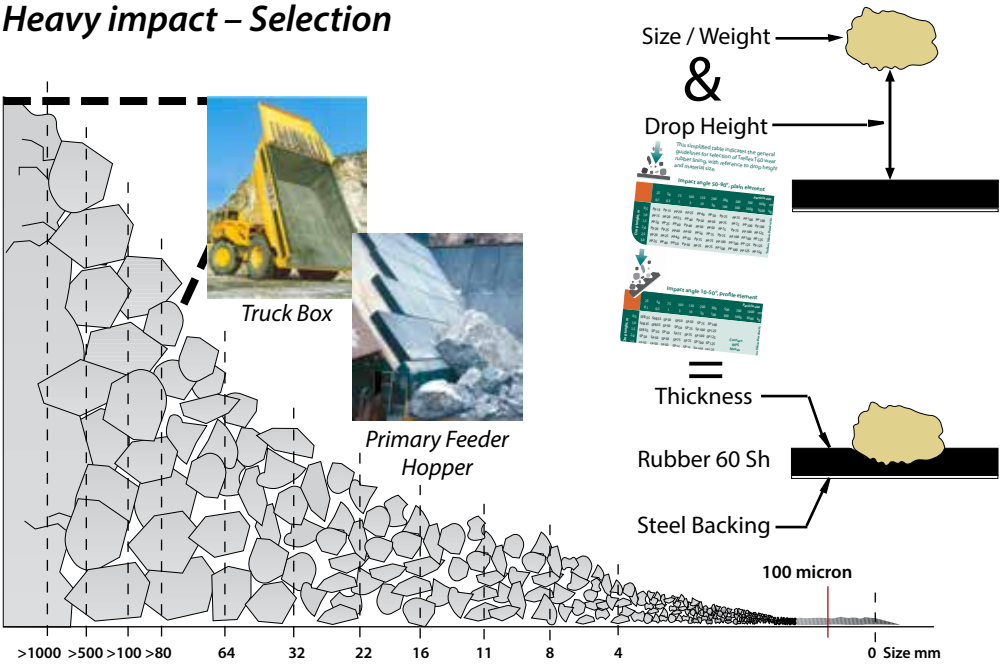

## Customized lining systems



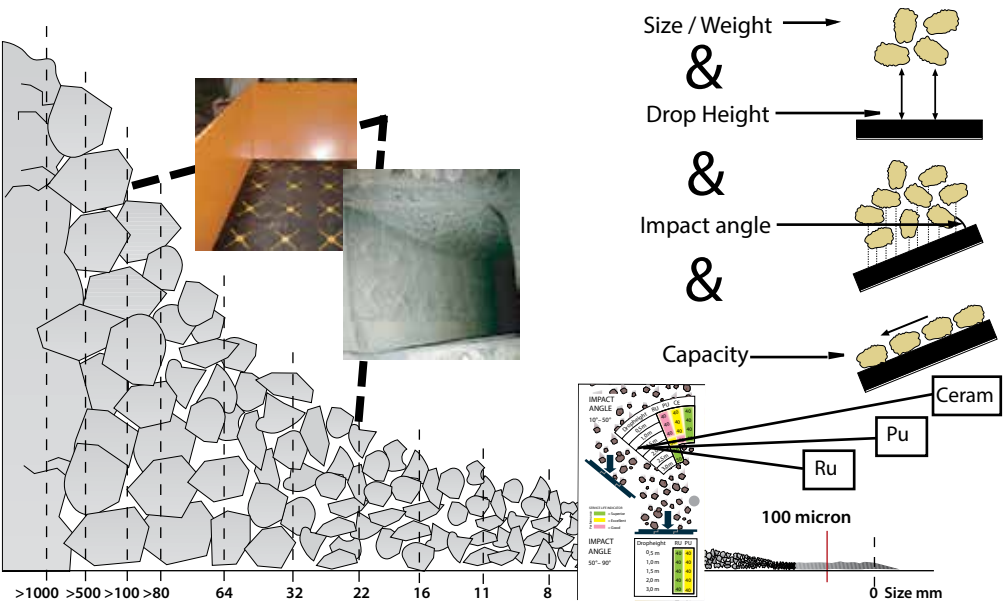
# Wear products – applications



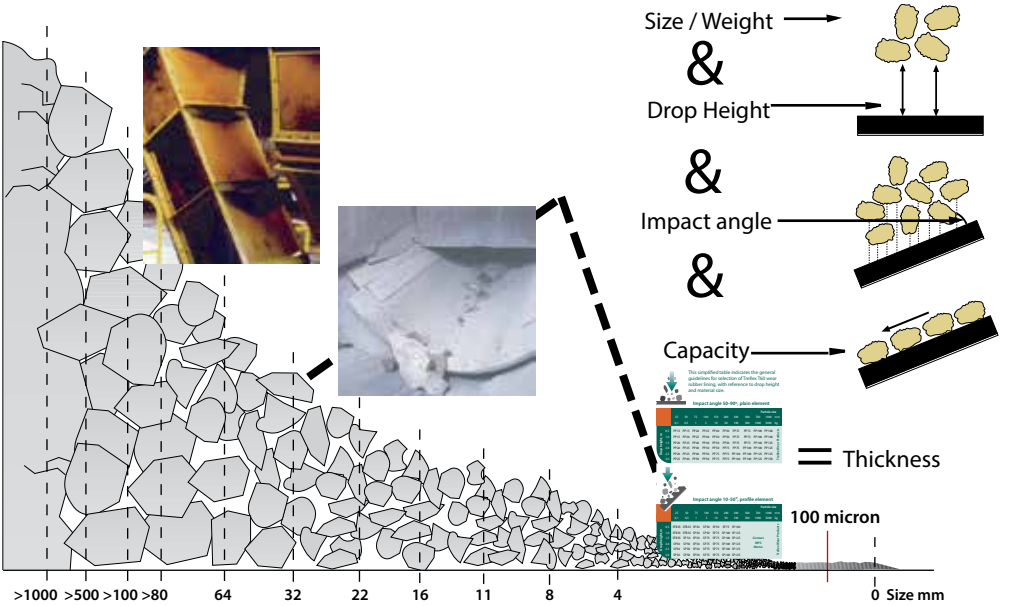
## *Heavy impact – Selection*




## *Impact and sliding – Selection (modules)*



## *Impact and sliding – Selection (sheeting)*

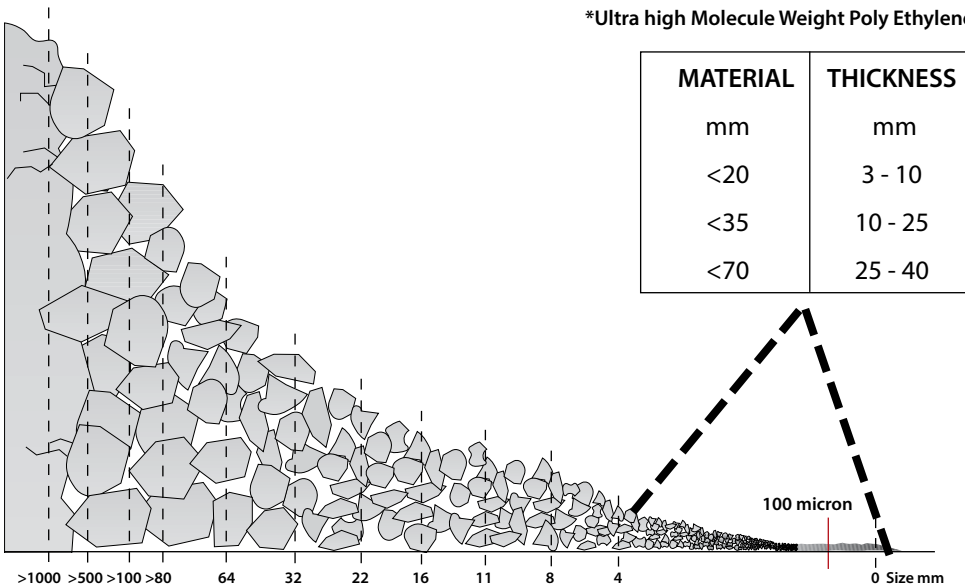



## *Sliding and build up – selection*

**Low Friction Elements – UHMWPE***

***Ultra high Molecule Weight Poly Ethylene**

| MATERIAL | THICKNESS |
|---|---|
| mm | mm |
| <20 | 3 - 10 |
| <35 | 10 - 25 |
| <70 | 25 - 40 |

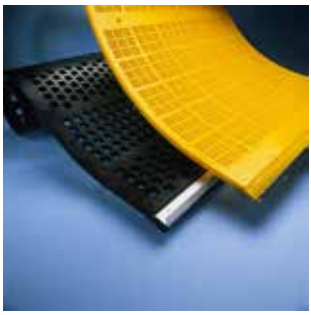


# Wear protection – Wear parts

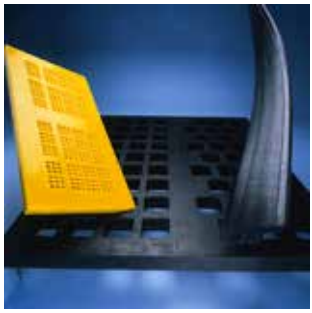
## Wear parts – Screening

*Self supporting rubber panels*

*Rubber & polyurethane tension mats*

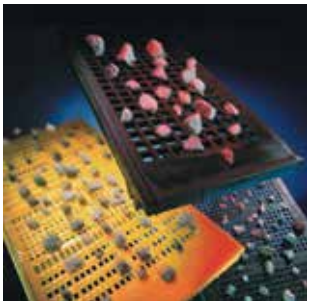


*Rubber & polyurethane bolt down panels*



*Antiblinding rubber mats*

*Rubber / polyurethane modular systems*

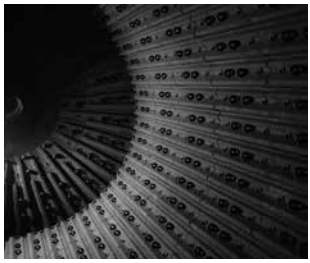


## Wear parts – Grinding

*Rubber linings*

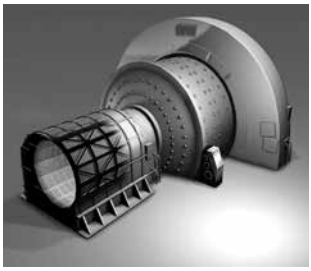
*Poly-Met® linings*

*Metallic linings*

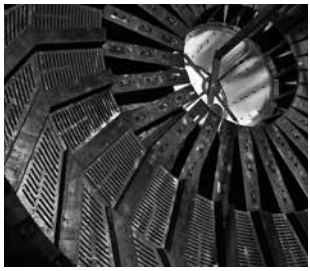


*Orebed® linings*

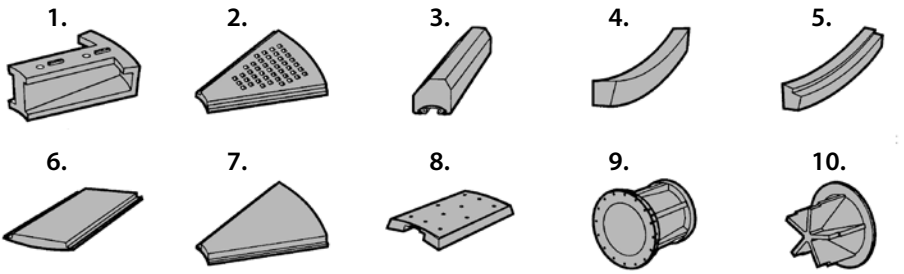
*Trommel screens*



*Discharge systems*

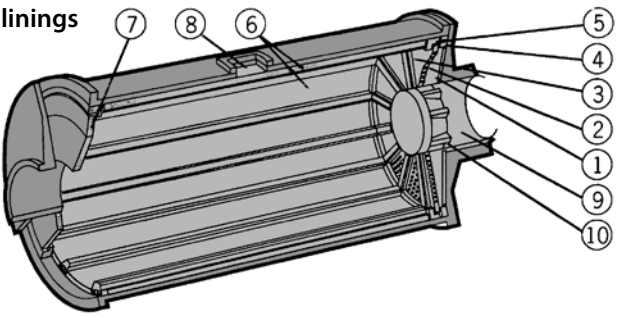


## *Tumbling mill – lining components*



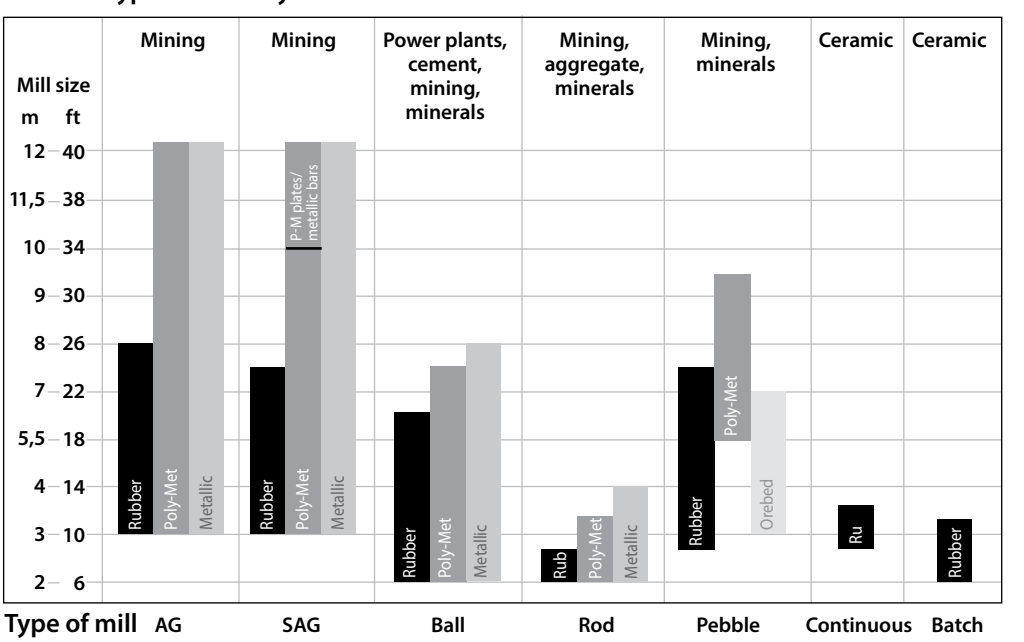

**Lining life time – standard linings "ball park figures"**

| Type of mill | Months |
|---|---|
| AG | 8 – 18 |
| SAG | 3 – 12 |
| Rod | 6 – 24 |
| Ball | 6 – 36 |
| Pebble | 12 – 48 |




## *Linings for mills**

**Type of industry**

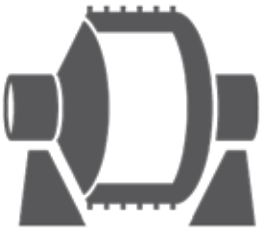



Discharge systems, trunnion linings and trommel screens are suitable for all sizes.

**This is a general view of suitable linings. Please contact Metso for more detailed information.*

## *Tumbling mill liners – material*

**AG mills**



**Dry:** Metal (white iron) or Cr-MO

**Wet:** Metal (white iron, Cr-MO or Poly-Met)

**SAG mills**

**Dry:** Metal (Cr-Mo)

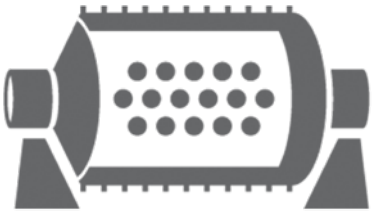
**Wet:** Metal (Cr-Mo or Poly-Met)

**Rod mills**

**Dry:** Metal (white iron) or Cr-MO

**Wet:** Metal (white iron) Rubber and Poly-Met, or Cr-MO
Head liners in rod mills are always Cr-Mo

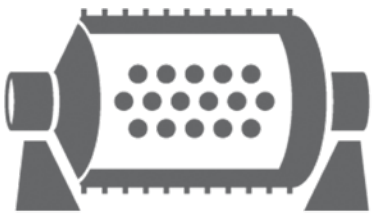
**Ball and Pebble mills**



**Primary or secondary mills:** Rubber or Poly-Met. Select type of insert based on level of impact in the mill.

**Regrind:** Rubber

**SRR mills**



**Dry-rod:** Metal

**Dry-ball**: Metal (or rubber if temperature not critical)

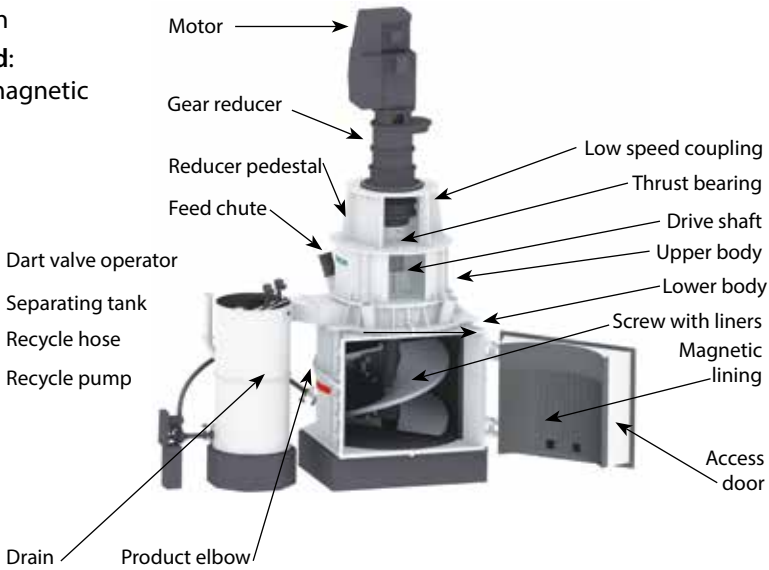
**Wet-rod:** Metal or rubber

**Wet-ball:** Rubber

## *VERTIMILL® – Liners*

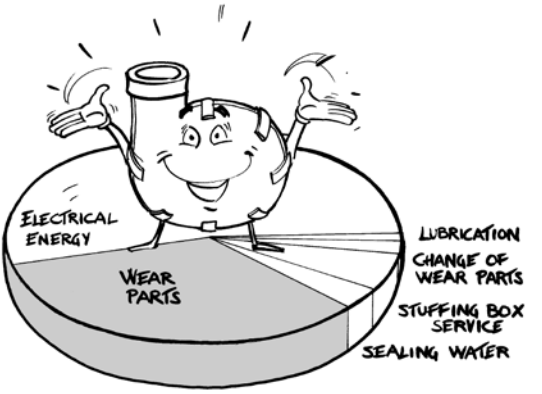
**Screw lined:**
with White iron

**Chamber lined**:
with Orebed magnetic liners.

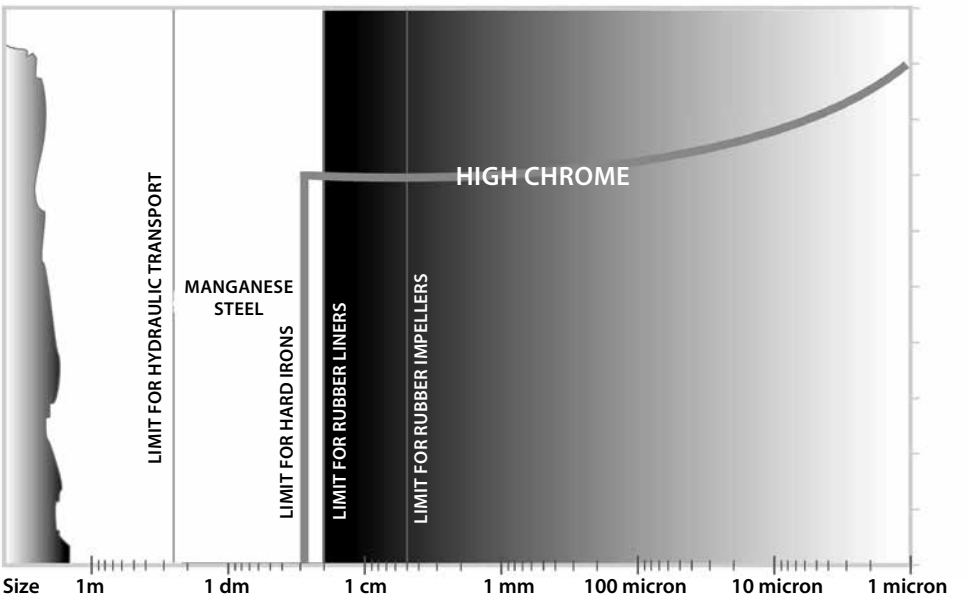


## *Wear parts – Slurry pumps*

Although the size of solids in a slurry is smaller than the feed size to a crusher or a grinding mill, wear represents a high operation cost for slurry pumping. This is naturally related to the high dynamic energy input in the form of high tip speed of the pump impeller causing both sliding and impaction wear.




### *Wear material vs size*




### *Wear parts pumps – metal*

**High chrome iron** (600Br) can be used at Ph down to 2.5. Standard wear material for most pump ranges.

**Ni – hard** with hardness exceeding 600 Br used mainly as casing material for pumps in grinding circuits or dredging.

**High density frozen Ni-hard** with hardness up to 900 Br used as casing material in primary grinding circuits.

**Manganese steel** with hardness up to 350 Br used for dredging applications.

### *Wear parts pumps – elastomers*

| Material | Physical properties | | Chemical properties | | | Thermal properties | |
|---|---|---|---|---|---|---|---|
| | Max. Impeller Tip Speed (m/s) | Wear resistance | Hot water, diluted acids | Strong and oxidising acids | Oils, hydro carbons | Highest service temp.(°C) Contin. | Occasion. |
| **Natural Rubbers** | 27 | Very good | Excellent | Fair | Bad | (-50) to 65 | 100 |
| **Chloroprene** 452 | 27 | Good | Excellent | Fair | Good | 90 | 120 |
| **EPDM** 016 | 30 | Good | Excellent | Good | Bad | 100 | 130 |
| **Butyl** | 30 | Fair | Excellent | Good | Bad | 100 | 130 |
| **Polyurethane** | 30 | Very good | Fair | Bad | Good | (-15) to 45-50 | 65 |

## *Something about ceramic liners*

Although ceramics have high resistance against wear, temperature and most chemicals, they have never really been accepted as day-to-day standards in Slurry Pumping.

Being both brittle and expensive to manufacture.

Development work on ceramics continue in an attempt to improve the possible acceptance.

## *Wear in slurry pipelines*

It is not easy to compare wear rates for different materials in a slurry pipeline depending on variations in duty. As a guide the figures below can be used (Transport and Road Research Laboratory test report of wear in slurry pipelines).

From the first of two programs of wear tests, the following conclusions were reached:

– Over the range investigated (2 to 6 m/s) wear varied according to a power between the square and cube of the velocity.

– Over the range investigated (5 to 15% by volume) wear varied more or less linearly with concentration.

– Over the range investigated (0.015 to 1.5 mm) wear varied more or less linearly with particle size.

– Emery (Mohs Hardness 8 to 9) produced a wear rate several times greater than that for silica sand (Mohs hardness 6 to 7).

In the second program the operating conditions were kept constant (velocity 4 m/s, 10% slurry) while 18 different pipe materials were compared.

Among them, three were rubber "a" (Trellex T40) - rubber "b" (Trellex T60) and rubber "c" (a British make).

| Material | Wear rate (mm/year) | Life expectancy of a 5 mm thick tube (years) |
|---|---|---|
| Rubber "a" (Trellex T40) | 0.13 | 38 |
| Zirconia/alumina ceramic | 0.15 | 33 |
| Ni-hard steel | 0.19 | 26 |
| Polyurethane "a" | 0.20 | 25 |
| Polyurethane "b" | 0.22 | 22 |
| Rubber "b" (Trellex T60) | 0.35 | 14 |
| Sintered alumina | 0.40 | 12 |
| Rubber "c" (not Trellex) | 0.61 | 8 |
| High Density polyurethane "b" | 0.67 | 7 |
| High density polyvinyl chloride | 0.87 | 5 |
| Unplasticised polyvinyl chloride | 1.27 | 4 |
| Stainless steel | 1.29 | 4 |
| Mild steel "a" | 1.57 | 3 |
| Polypropylene | 1.59 | 3 |
| Mild steel "b" | 1.69 | 3 |
| ABS | 2.52 | 2 |
| Asbestos/cement | 94.68 | – |

# *Operation and environment – Introduction*

From environmental, health and safety point of view most mineral processing operations have some negative effects on the working environment.

The main problems are related to

- **Dust (dry plants)**
- **Noise (wet and dry plants)**
- **Pollution (emissions other than dust to air and water)**

Regarding pollution of water and air by various emissions we refer to the process sections 5 and 6 above (enrichment and upgrading).

# *Dust*

## *Dust – Size*

When energy is introduced to rock, ore or mineral crystals will generate a dust emission. *With dust in mineral processing we practically understand particles below 100 micron in size*. Above this size dry particles are easy to control and are quite harmless.

## *Dust – Chemical composition*

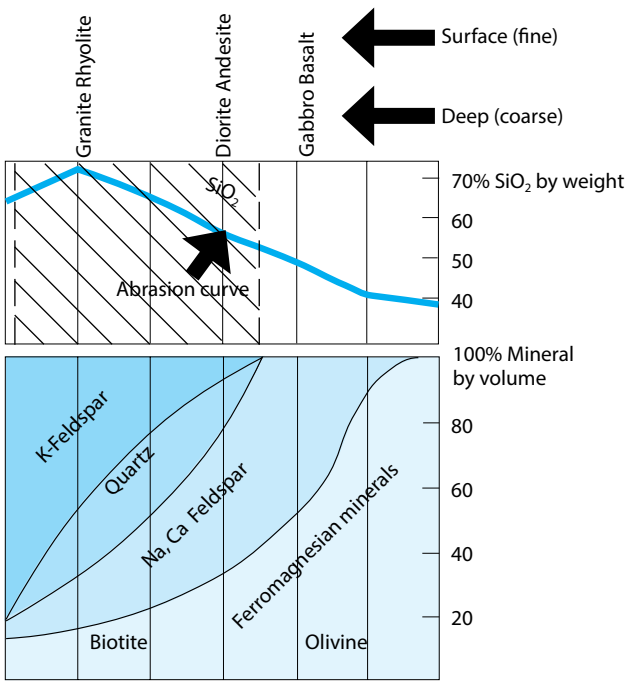
A parameter of interest is the chemical composition. Hard rock in many cases is hazardous due to the silica content.

*Free quarts ($SiO_2$) is extremely dangerous and so are the rocks containing quarts like granite, gneiss a.o, see figure below. Fine silica can cause silicosis, a deadly lung disease. Mg-silicate of asbestos type is also very dangerous when inhaled, causing lung cancer.*

As many of the silicates are hard and abrasive these dust fractions also are causing heavy wear when exposed to bearings, motors etc.

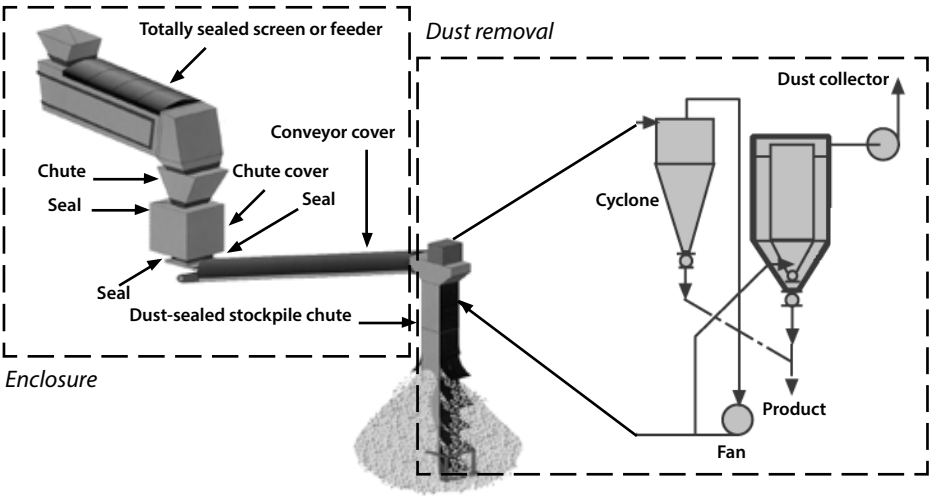
**Dust – $SiO_2$ levels**

Dust fractions of non - silica type are normally not too dangerous for the operators and give more like a "housekeeping" problem.




*$SiO_2$ levels in magmatic rock*

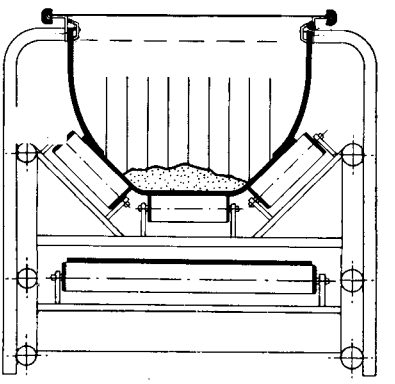
## *Dust control – Basic*




**Some guidelines:**

1. Let the dust *report to the material flow* by using dust suppression or enclosure.
2. Suppression by water or foam is cheap and handy but can only take care of the coarser dust. Fine dust will remain a problem. If too much water is used the dust will turn to sticky clay, causing down time in operation and freezing in cold climate.
3. *Enclosures* of machines are very effective provided that you only encapsulate the dust emitting part of the machine, not drives or other moving parts. Enclosures are also very effective against wind emission of fines from conveyors and for sealing off transfer points, see below.
4. *Dust removal* by ventilation is used when the dust is the product (dry grinding of filler fractions) or when dust is not allowed in the final product or in the processing system, see ventilation criteria below.

*Equipment enclosure*



*Wind enclosure*

## *Ventilation criteria*

Dust capture velocity in m/s (ft/min)

= Ventilation criteria **(Vc)** in $m^3/s/m^2$ ($ft^3/min/ft^2$)

= Air volume needed per open area of enclosure

Calculation of ventilation systems for dust removal is a tricky thing. Some estimation figures below:

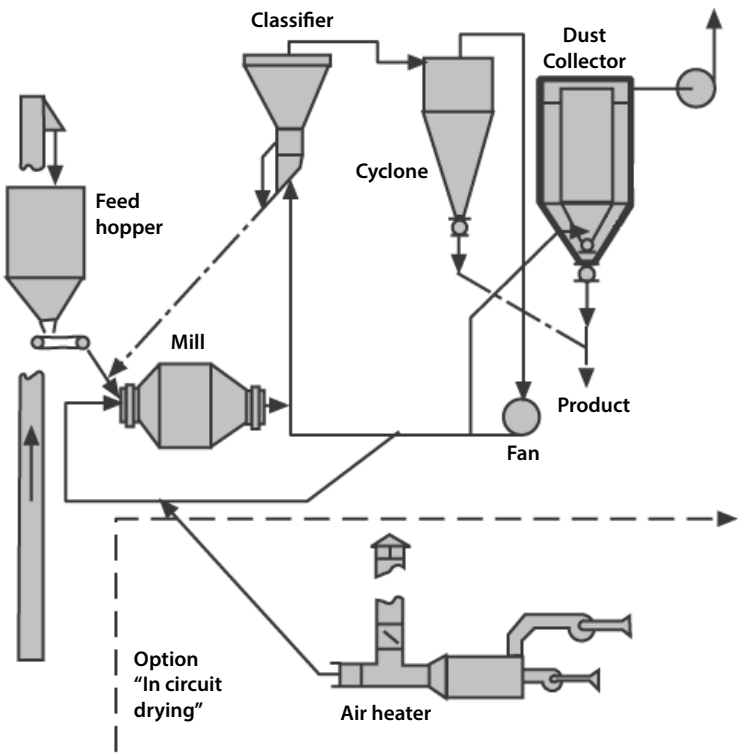
| Application | Vc | Comments |
|---|---|---|
| Feeders, surge bin openings | 1,02 (200) | General value for low-energy operations |
| Transfer points | 2,33 (1500) | per enclosure area |
| Screens | 0,26 (50) | per screen area |
| Crushers and dry mills | 1,5 (300) | not for air swept mills |

## *Dust collection*

The dust removal and dust collecting systems are very similar to a normal dry classification circuit. Dry classification is in fact a dust removal system where the max size of the dust is controlled by a classifier (or ventilation criteria), See below.

Primary recovery of dust is normally done in a cyclone taking the major part. The final recollection is done in a wet scrubber or a fabric filter.

Wet scrubber has an advantage over fabric filter when the dust is combustible. In all other cases the dry fabric filtration is more effective as no sludge handling is required (being the case with wet scrubbers).



# *Noise*

## *General*

In mineral processing there are a number of machines considered to be very noisy (crushers, screens and grinding mills are typical).

By definition noise is an "undesirable" sound. As sound is **air borne sound pressure variations,** we have to find a sound pressure level, which can be tolerated by the operators. Noise is not only harmful to the hearing but also affects the heart action and the ability of concentration. It also restricts verbal communication and the observation of warning signals or dangerous situations.

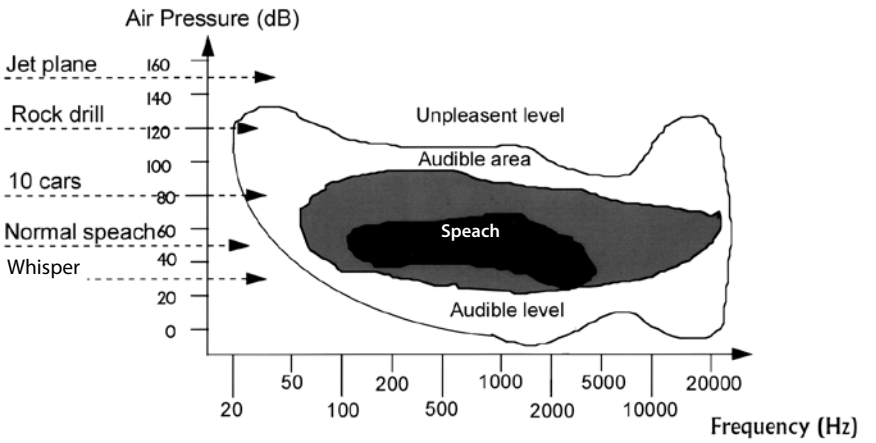
## *Sound – basic*

The human sound pressure range from lowest sound to be heard and highest sound to stand without pain is
**from 0,00002Pa (2µPa) to 20 Pa.** (1 psi = 6,89kPa).

*To be more practical the sound pressure range above is converted to a sound pressure level by the formula:*

**Lp = 20x log P/Po** ***(Po = 2 µPa) converting the range above over to 0-120 dB (decibel)!***

| **Experienced sound** | **change of dB** |
|---|---|
| Double sound level | + 10dB |
| Double sound sources | + 3 dB |
| Double the distance to sound source | – 6 dB |




*Hearing range for a normal ear*

The lower limit is called the threshold of hearing and has a maximum sensitivity around 3500 Hz (resonance frequency of the ear).

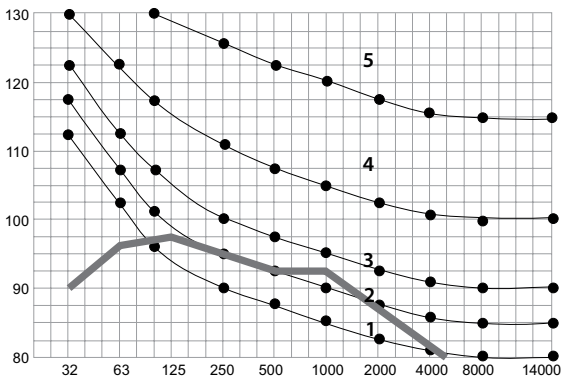
The upper line is the 120 dB sound pressure line (the pain line)

**Mechanical noise is measured in dB (A)** indicating that an A-filter is used, damping lower frequencies (of less harm to the operators).
**Infra-sound** is sound with a frequency below 22 Hz. (Can be harmful at longer exposures).
**Ultra-sound** is sound with a frequency above 18 kHz. (Can be harmful at longer exposures).

### *Noise – exposure risks*

For continuous sound with a wide frequency range, a sound level below **85 dB(A)** is acceptable for an 8 hour exposure per day with respect to the risk of hearing damage.

If the sound level is higher an octave band analysis is necessary. This curve is compared to the standard risk curves, see below.




Maximum acceptable exposure per 8 hours:

5. Less than 5 min

4. Less than 20 min

3. 1 - 2 h

2. 2 - 5 h

1. 5 - 8 h

= middle frequency of octave Band (Hz) (Impact crusher on 1 m distance).

## *Noise reduction*

There are 4 main ways to reduce the noise levels for processing systems including crushers, mills and screens.

- Optimum operation
- Use of "internal" polymers (wear material and wear products)
- Use of "external" polymers (dust enclosures)
- Enclosure with noise reduction walls

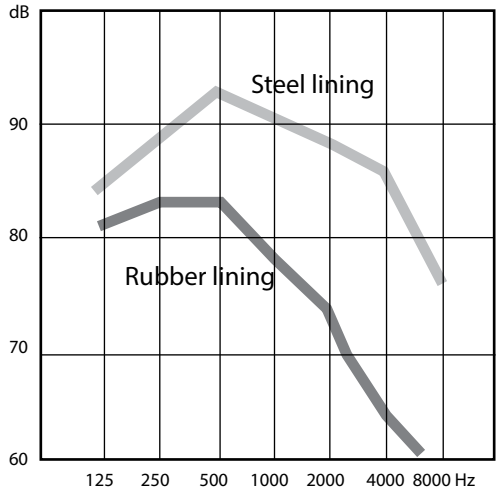
### *Optimum operation.*

Mass flow equipment like crushers and screens are normally lower in noise when they are operated under optimum conditions and the material flow is absorbing part of the noise (e.g. choke fed cone crushers). Reduced circulating loads also lead to reduced noise levels.

### *Internal polymers*

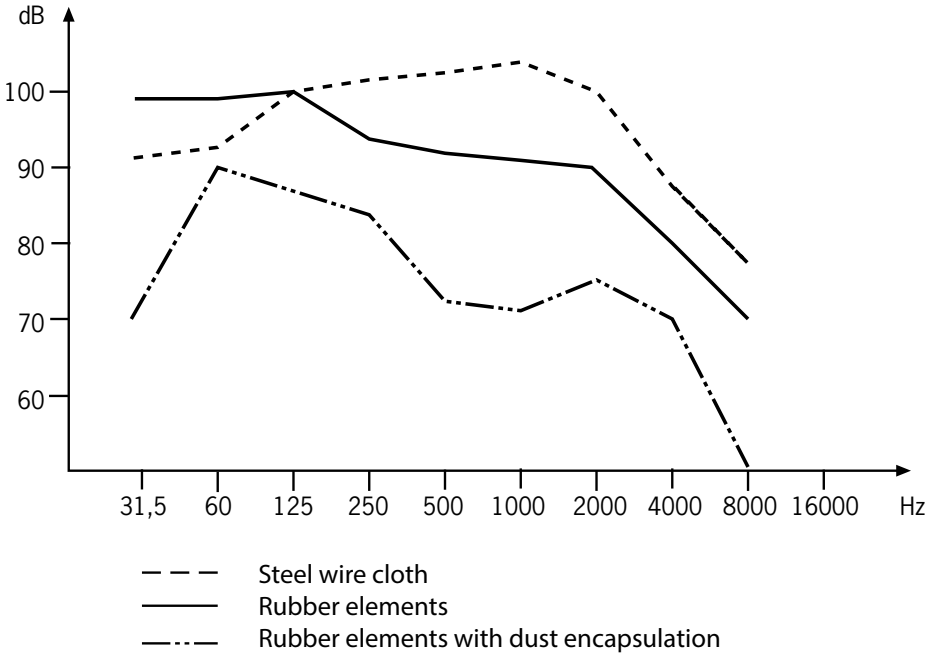
The use of polymers as mill liners, screening media and wear protection in material handling systems (chutes and transfer points) have a dramatic effect on noise reduction.

For grinding mills a rubber lining can reduce the noise level up to 10 dB(A) compared to a steel lining.



### *External polymers*

Using polymers as dust sealing enclosures of crushers, screens, conveyors, chutes, transfer points etc. will give a noise reduction of approx. 5-10 dB (A).
The difference for a screen with steel wire deck and rubber deck is shown below.



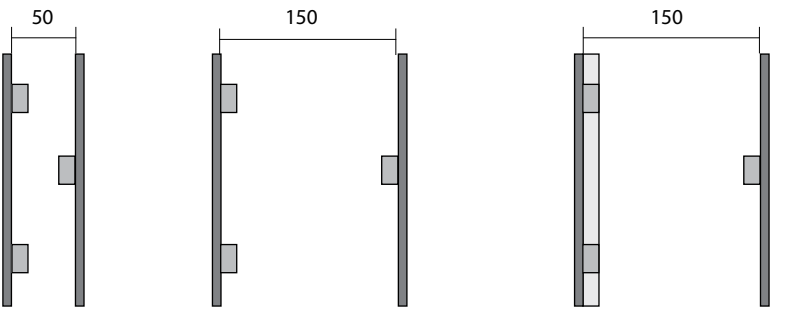

**A simple rule: The more polymers used for various purposes in the mineral process systems the lower the noise levels!**

### *Noise reduction walls*

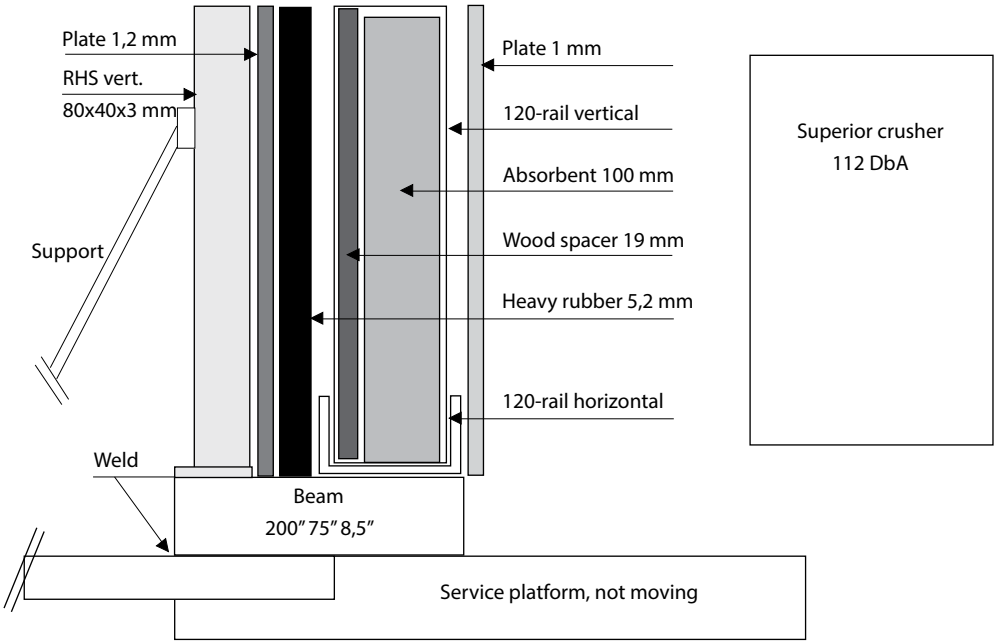
Enclosure is an effective way of reducing noise. Enclosure can be more or less extensive (enclosure of drive or machine or both). With a total enclosure noise levels can drop by 10-15 dB (A).

Depending on duty the design of the noise reduction walls can differ in design:

Light and medium duty walls



### *Heavy duty crusher wall , cross section*




## *Ear protection*

When working in environments with continuous and high noise levels it is important to use ear protection all the time. Also at sound levels of 75-80 dB (A) it is to be recommended to use ear protection even if recommendation says something else. Reason is that long exposure also at these levels can cause impairment of hearing.

Good rules about ear protection:

- Take some "noise breaks" now and then
- Go for regular hearing tests
- Check your ear protection equipment at certain intervals

# Process system – Introduction

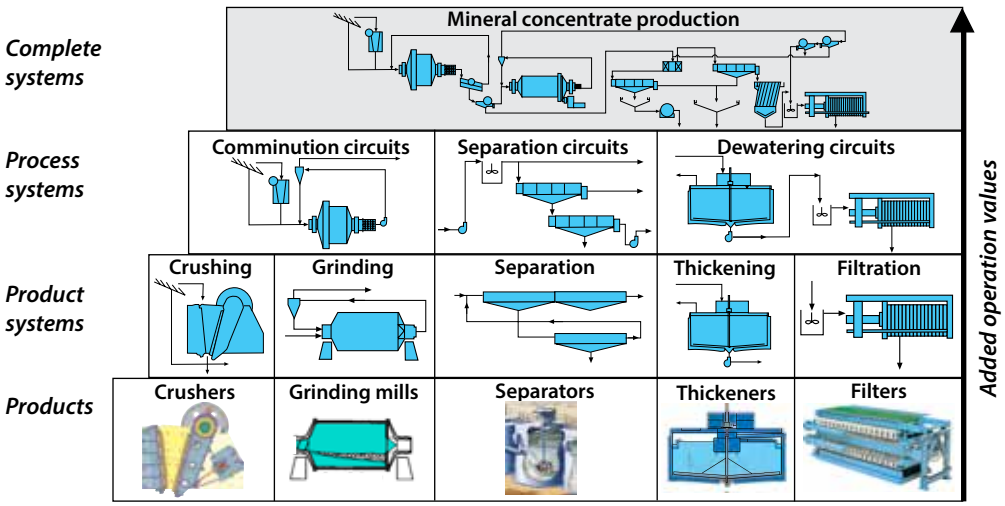
A machine working in a mineral process flow cannot perform better than the process environment will allow it to.

Parameters like type, size and amount of feed, % solids in slurries, additives, discharge conditions etc. will always guide equipment performance and operation economy.

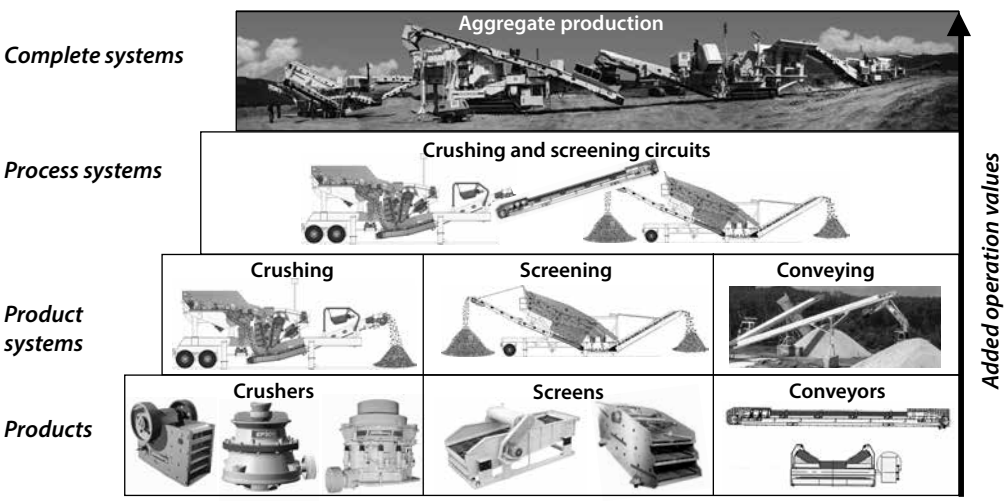
There is a strong trend amongst both suppliers and users to work in terms of systems, meaning solutions to various operation problems more than installing equipment. This will effectively increase the operation values as presented in section 2:9

Examples covering systems levels and system modules are shown in this section.

## System levels in ore / Minerals processing



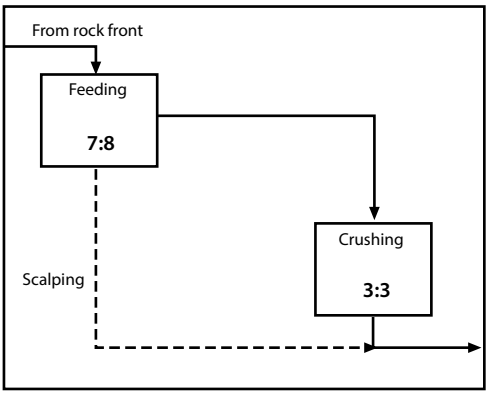

## System levels in rock processing (Quarrying)



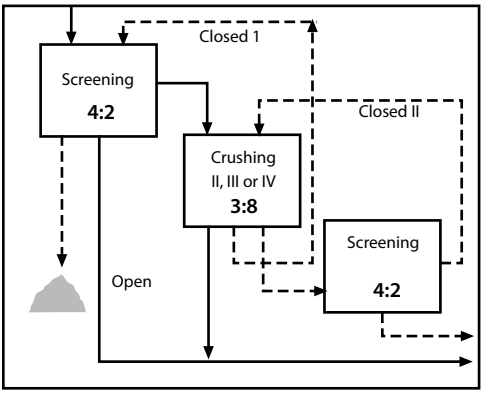
## *System modules – Aggregates*

A good way to understand and work with process systems is to use **system modules** in various combinations.

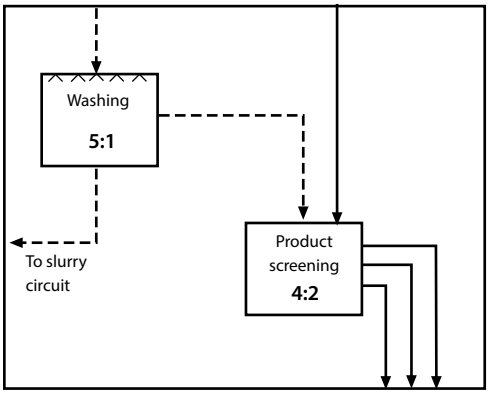
**Primary crushing module**



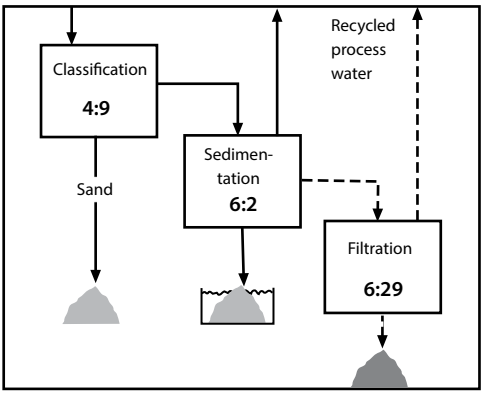

**Intermediate crushing module**




**Final products module**

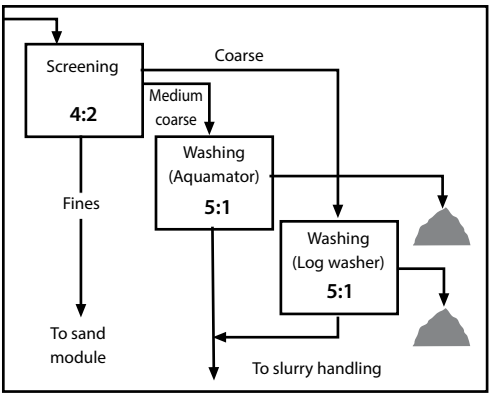



**Slurry handling module**

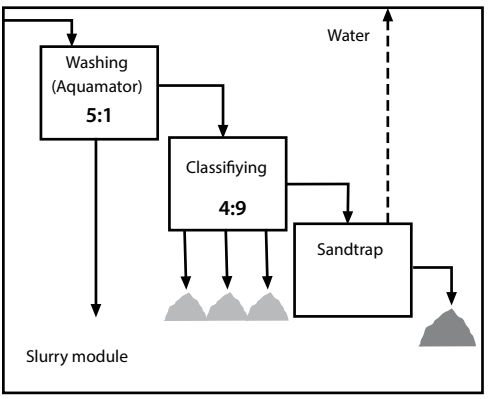



## *System modules – Sand and gravel*

**Sand and gravel module**



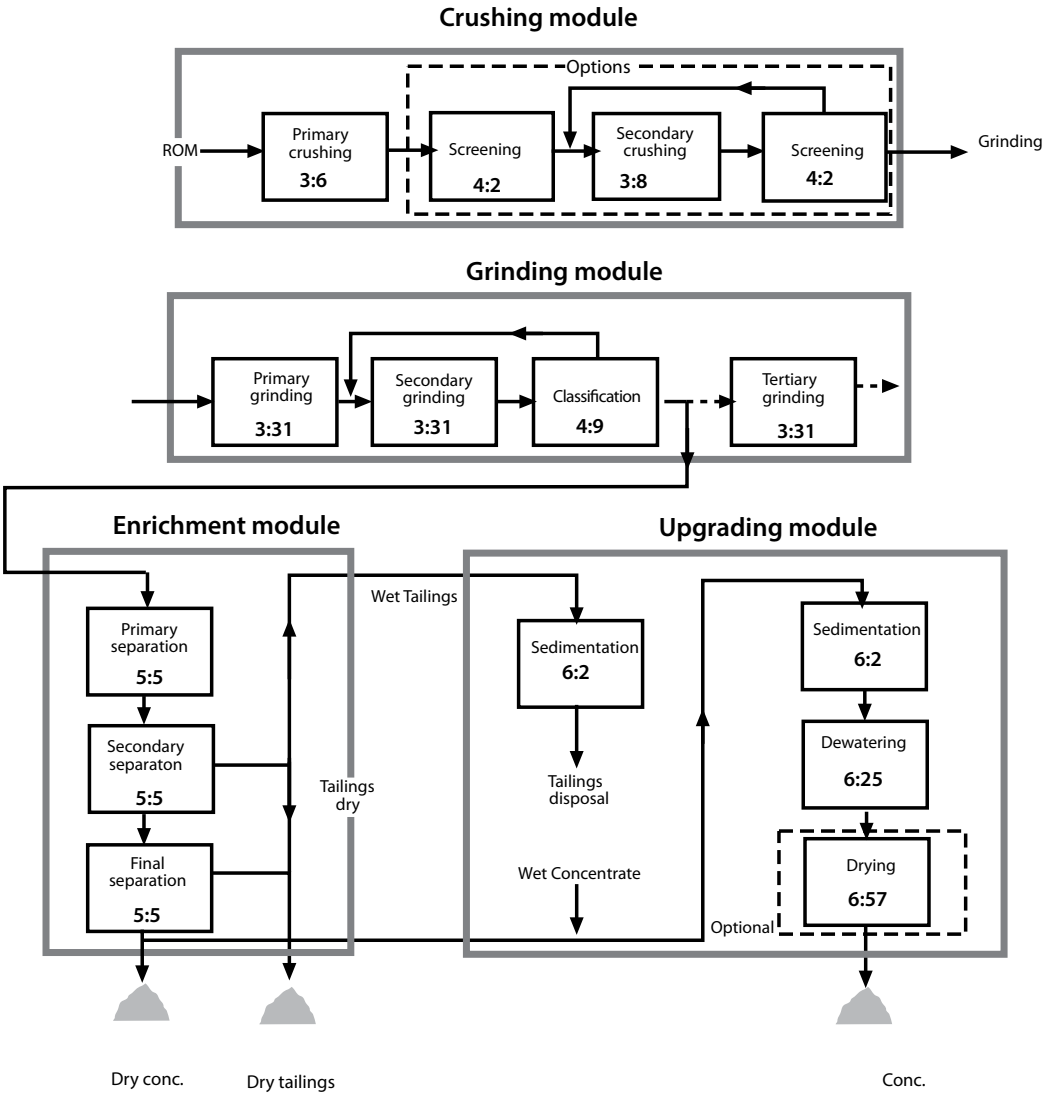

**Sand and gravel module**




- - - - - = option or alternative

**7:5** = referring to actual chapters and pages

## *System modules – Ore and minerals*

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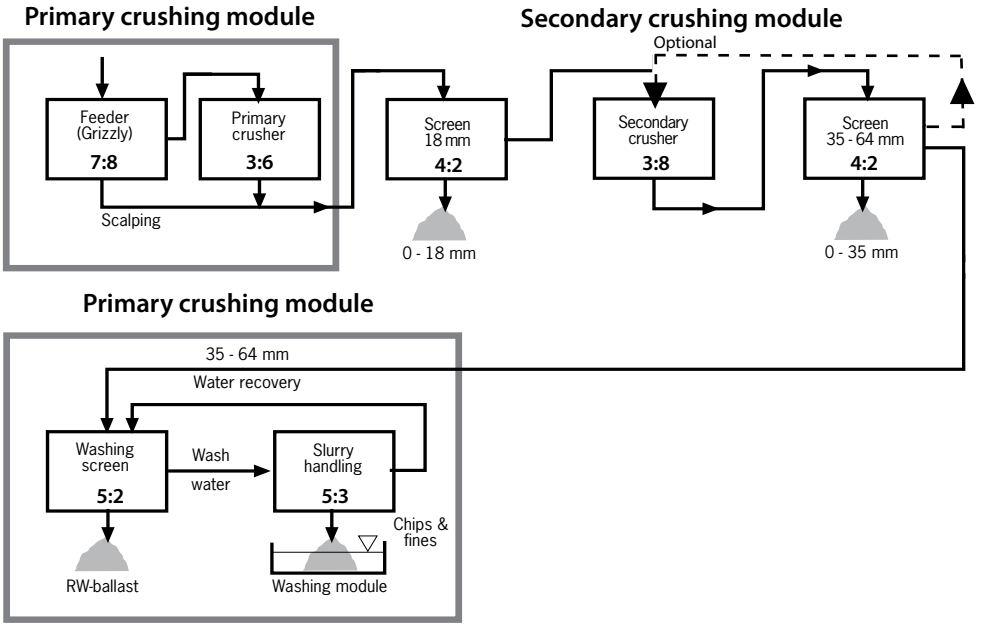
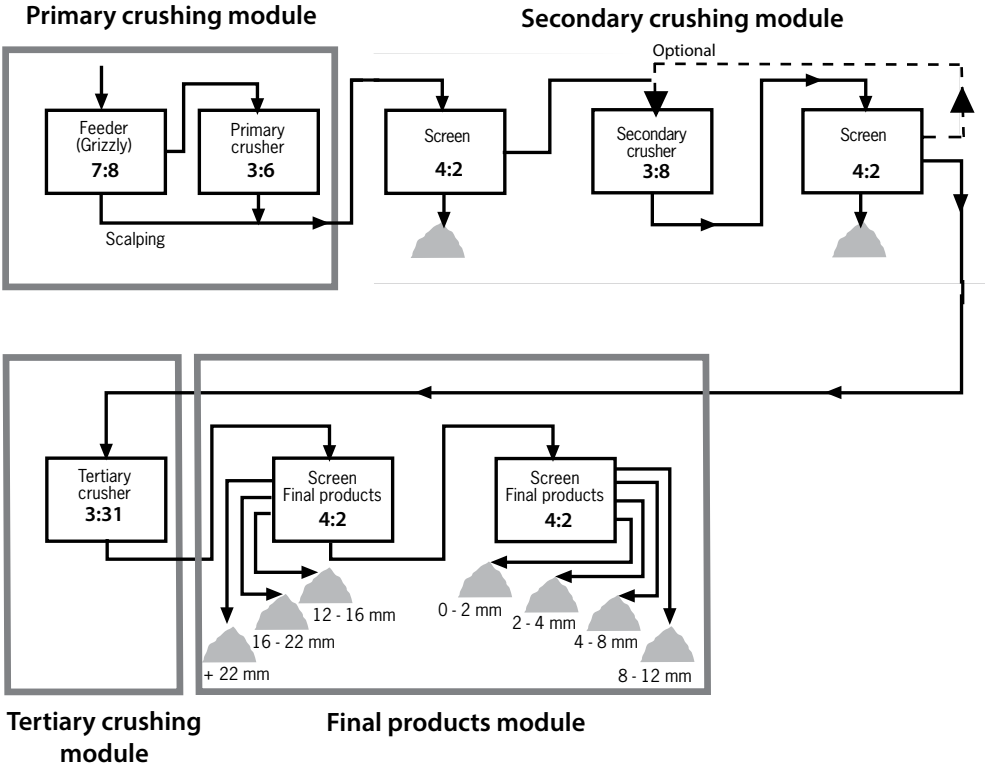
**7:5** = referring to actual chapters and pages

## *Process system – Railway ballast*




## *Process systems – Asphalt / Concrete ballast*

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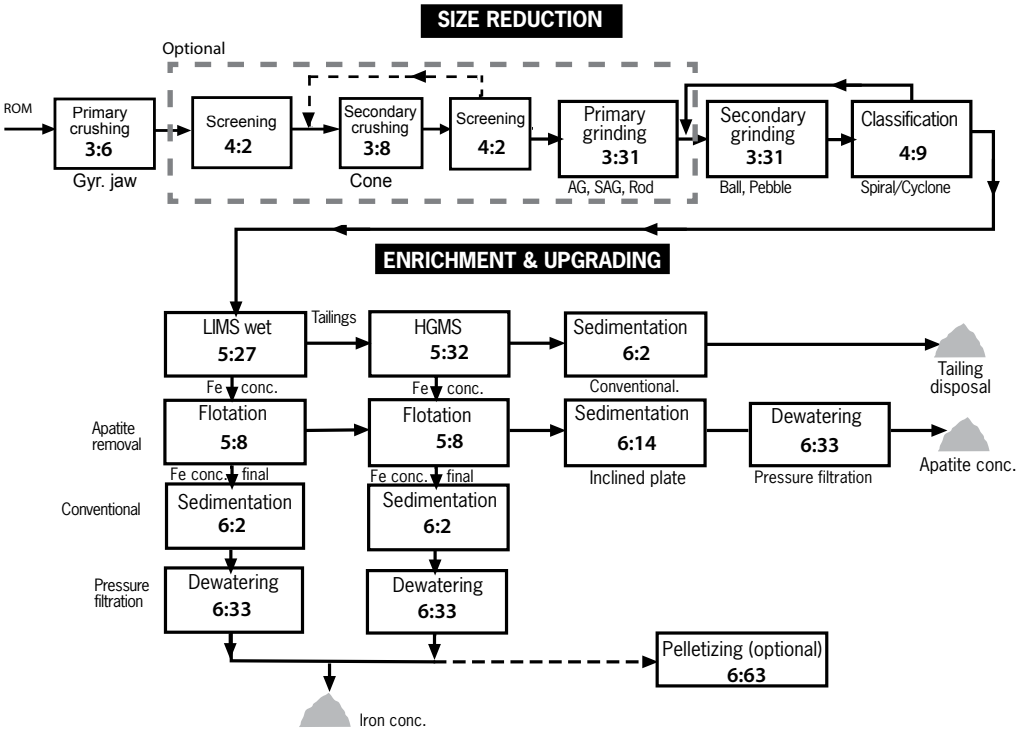
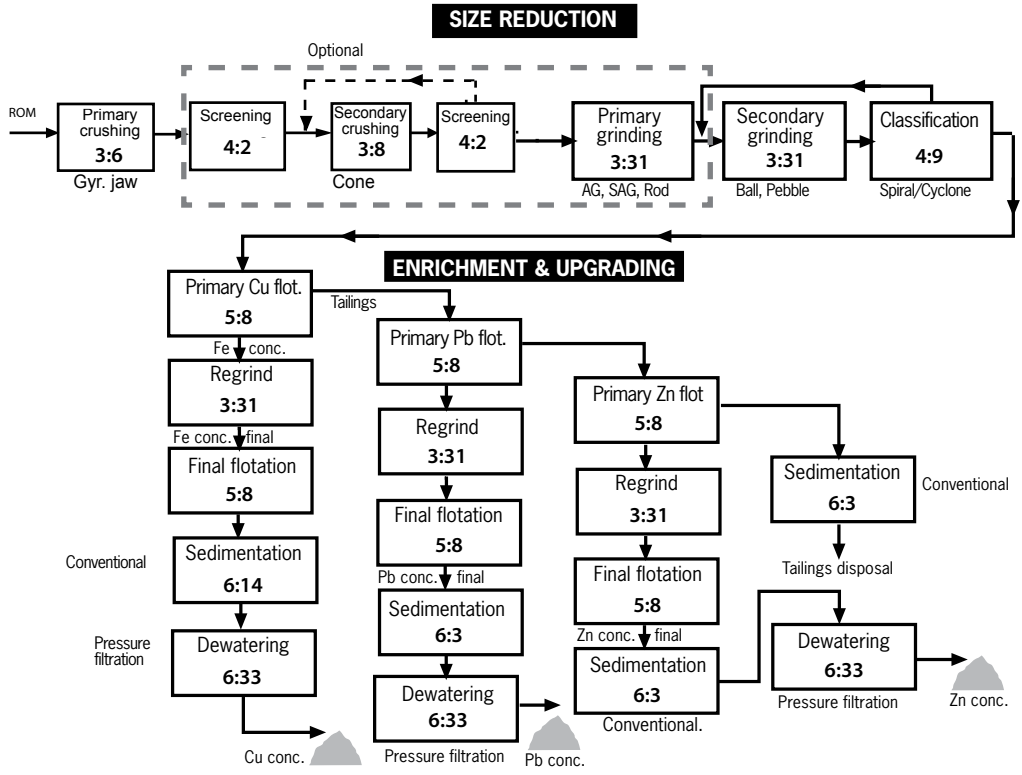
**7:5** = referring to actual chapters and pages

## *Process system – Ferrous ore (hosting apatite)*




## *Process system – Base metal ore*

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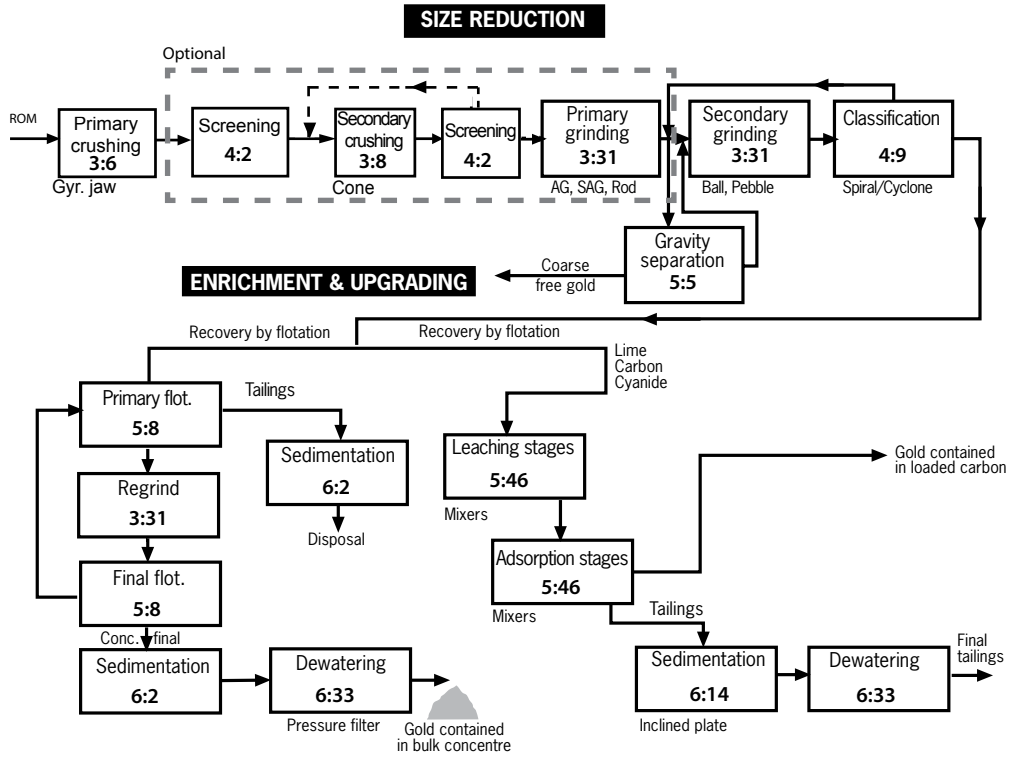
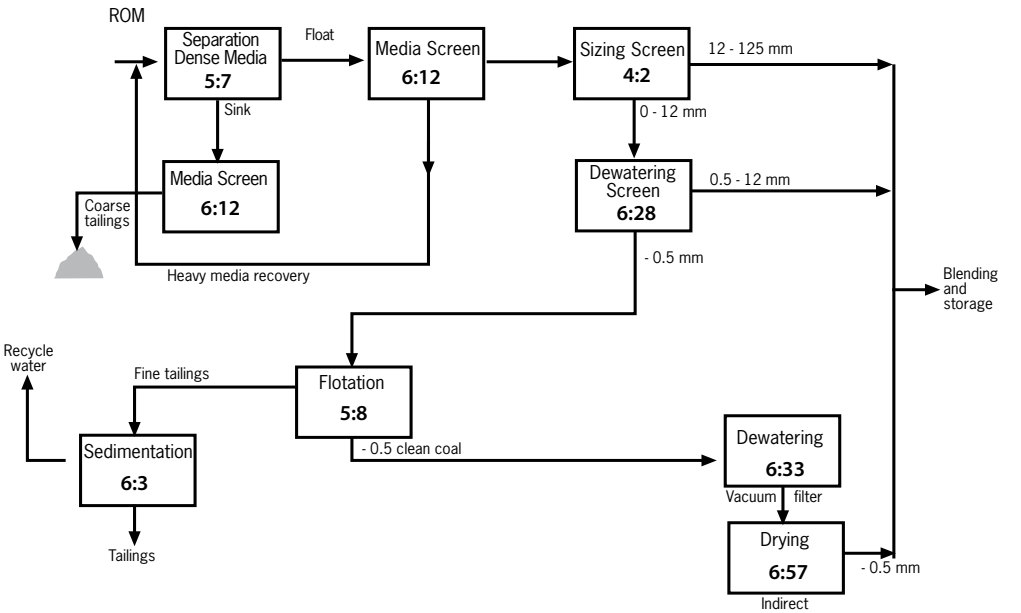
## *Process system – Gold bearing ore*




## *Process system – Coal*




Process system

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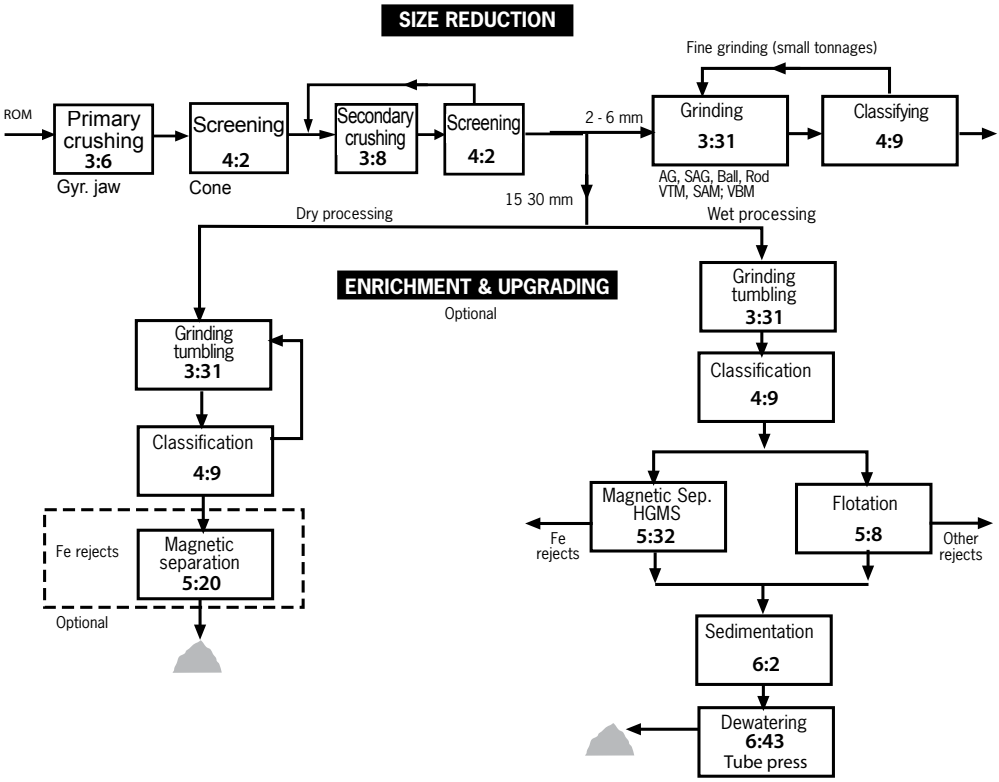
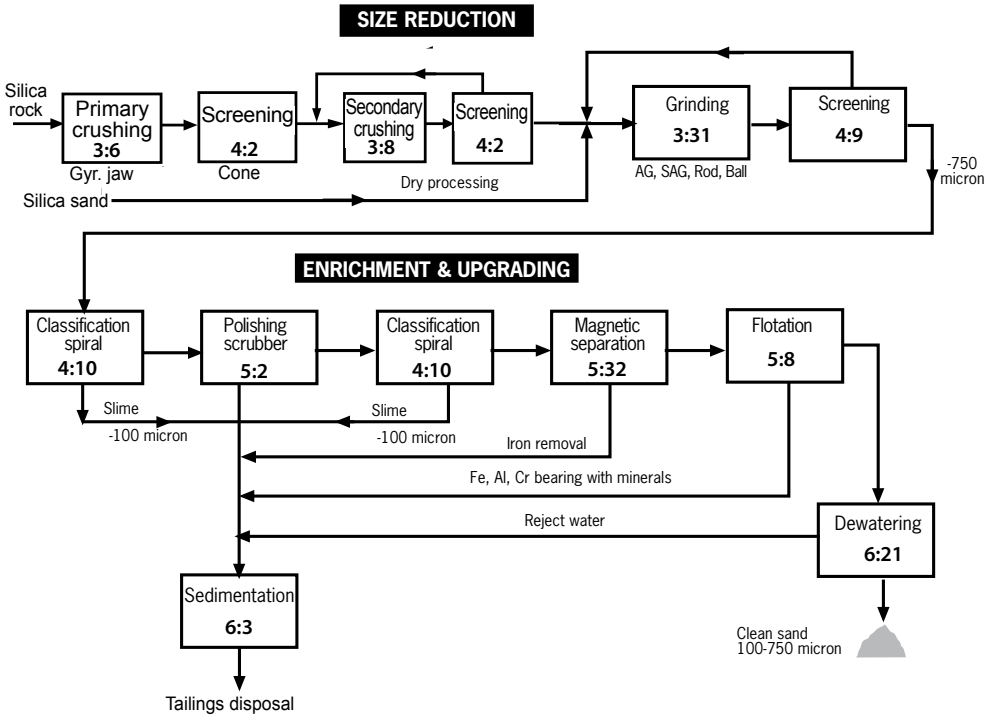
## *Process system – Industrial mineral fillers*




## *Process system – Glass sand*

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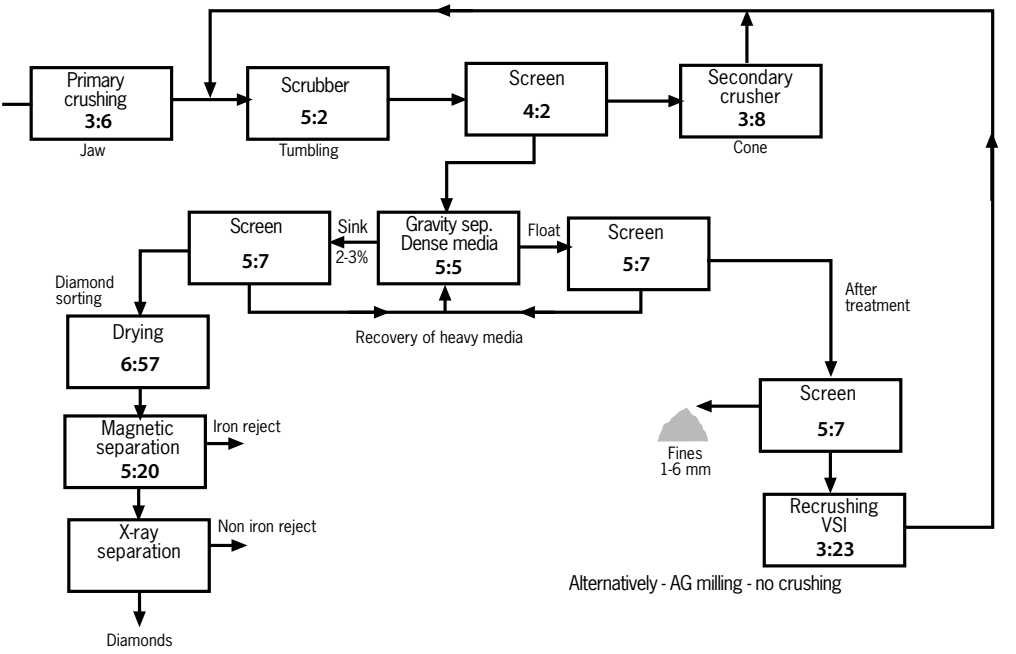
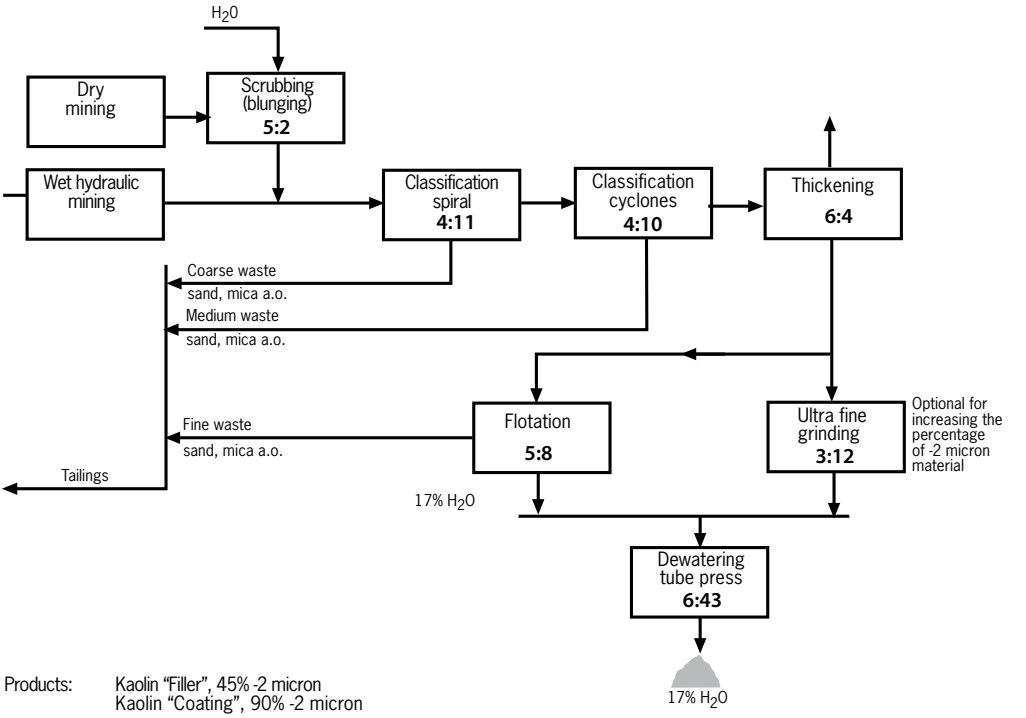
**7:5** = referring to actual chapters and pages

## *Process system – Diamonds (Kimberlite)*




## *Process system – Kaolin*




Products: Kaolin "Filler", 45% -2 micron
Kaolin "Coating", 90% -2 micron

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**7:5** = referring to actual chapters and pages

## *Mobile systems*

In modern quarrying, mining, tunnelling and recycling operations the use of mobile process systems is increasing dramatically.

Particularly at rock front operations the technique of "moving the process equipment closer to the front end" using mobile crushing and screening units in many cases gives remarkable cost savings.

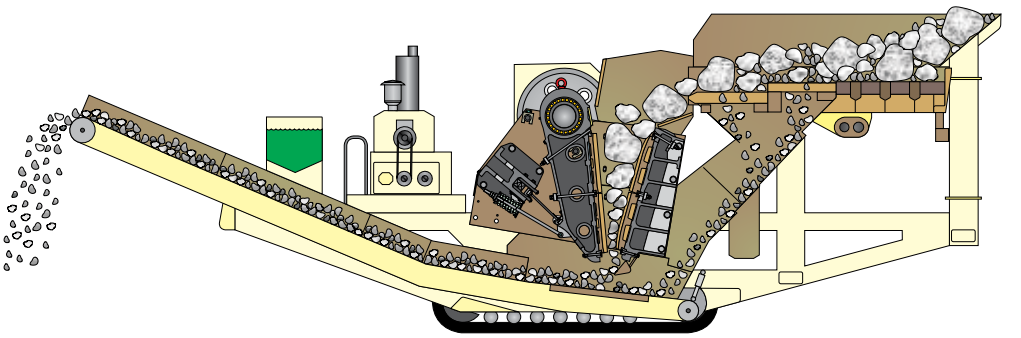
These mobile units represent one or more complete machine functions including materials handling, power supply etc. Advanced process control secures the "intelligence" of the system.

### *Mobile crushing and conveying system*

Key arguments for mobile equipment vs stationary equipment and damp truck haulage are:

- Less hauling – less costs
- Less front road maintenance
- Less exhaust gas and dust emissions
- Improved working safety
- Improved flexibility

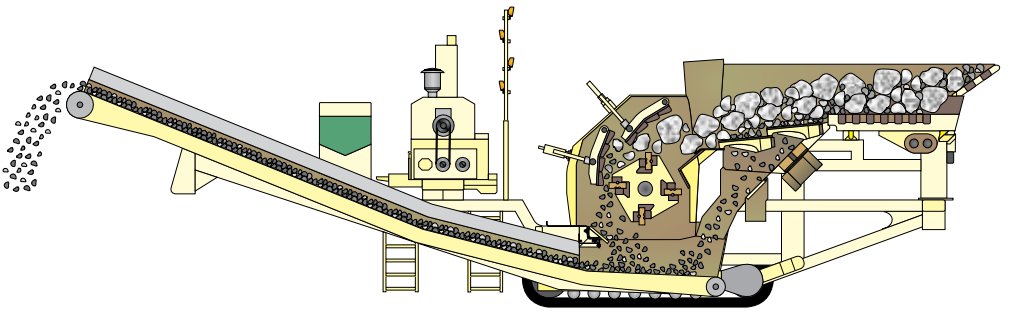
## *Primary jaw crusher + Grizzly (typical)*



| Type* | Max feed/product size mm (inch) | Capacity tph | H/W/L m (ft) | Weight ton |
|---|---|---|---|---|
| LT110 | 670 / 250 (26/10) | 700 | 4.4/3.0/17.4 (14.5/9.1/57.0) | 60 |
| LT125 | 800 / 300 (31/12) | 800 | 5.7/4.0/15.8(18.6/15.2/51.1) | 86 |
| LT140 | 900 / 350 (35/14) | 1200 | 6.3/4.3/16.4(20.8/14.1/53.1) | 110 |
| LT160 | 1040/ 400 (41/16) | 2000 | 7.6/5.9/20.2(25.0/19.3/66.7) | 220 |

*LT110 refers to Jaw crusher type C110, LT125 to Jaw crusher type C125 etc. see further section 3.

## *Primary impact crusher + Grizzly (typical)*





| Type* | Max feed/product size mm (inch) | Capacity thp | H/W/L m (ft) | Weight ton |
|---|---|---|---|---|
| LT1415 | 1000/200 (40/8) | 800 | 5.4/4.0/15.8 (17.7/13.1/51.1) | 73 |
| LT1620 | 1300/200 (52/8) | 1200 | 6.5/4.8/18.5 (21.3/15.7/60.7) | 170 |

*LT 1415 refers to Impact crusher type NP1415, LT 1620 to Impact crusher type NP1620 etc. see further section 3.

## Metso simulation tools

Bruno™ is a steady state simulation tool for the design and evaluation of crushing and screening plants. It is easy-to-use and the designer can quickly evaluate flowsheet options, select appropriate Metso equipment and forecast product quality and overall instantaneous system productivity.

For more information and/or to acquire a copy of the Bruno software, please contact your local Metso sales office.

## Consulting business

### Technology development

Technology Development, a division of Metso – Mining and Construction – Mineral Process Solutions Business Line, offers a global consulting service focused on simulation and automation.

In the area of Simulation Metso has a unique dynamic population balance modeling and simulation tool – Metso ProSim™ - which can be used to analyze, optimize and design mineral processing circuits. In addition to the usual suite of unit operation models, Metso ProSim™ utilizes multi-component structure and also allows for the inclusion of maintenance outages – planned and unplanned – moving toward the virtual plant. Metso also has a world-class multi physics simulation capability that allows for mircoscale analysis, design and optimization of components of process equipment, looking at productivity, product quality, wear and potential failure modes. This work involves the use of DEM, CFD, SPH, DGB, and other complex solution methodologies, requiring super computing platforms to deliver timely results. Finally, as part of the automation work (OCS© – 4D), Metso provides dynamic simulation capabilities that can be used to help design resilient process control solutions, develop custom advanced control strategies, and for training plant operators on new circuits.

In the area of Automation, Metso offers comprehensive control systems integration services which can include full electrical and instrumentation capabilities. In addition, process audits and training programs centered around regulatory automation needs are also part of the scope of services. Metso Computer Based Training (CBT) is also available to train plant operators on all aspects of the operation of comminution and/or flotation circuits Metso is also a leader in the field of Advanced Process Control (OCS©: model-based expert control) and Advanced Sensing (Visio™: machine vision, Audio™: machine acoustics), and is moving quickly into the related fields of Abnormal Situation Management and real-time data and image mining.

The objective of the Technology Development consulting activities is to identify and implement cost effective ways to improve plant productivity and lower unit costs, while respecting and enhancing the operational integrity and safety requirements of a plant.

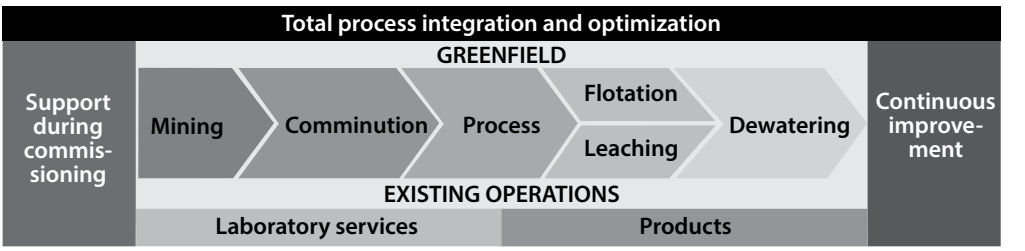
## *Process technology and innovation*

PTI, Process Technology and Innovation, a division of Metso – Mining and Construction – Services Business Line, offers a global consulting service for the mining and construction industries.

Process Integration and Optimization, PIO, is the development of integrated operating and control strategies from the mine to the plant that maximise throughput, minimise the overall cost per tonne and maximise profitability.

We offer consulting, laboratory and pilot plant services, and have developed supply and support for a range of products that have been designed to enhance the operation of mineral processes. Significant increases in throughput (5 to 30%) and metal recovery, cost and energy reduction, as well as overall process efficiency increases (from the mine to the plant) have been achieved at a number of operations worldwide.

PTI's particular focus is providing the industry with Total Process Integration and Optimization including optimization of the mining (drill and blast), comminution, flotation and dewatering processes for both Greenfield and existing operations. The main objectives are to reduce operating costs, increase production rates and improve overall process, energy and water efficiency.




For more information on Metso's technology consulting businesses, please contact your local Metso sales office.

# Conversion factors

## Length

1 inch = 25.4 mm

1 foot = 0.305 m

## Area

1 square inch = 645 $mm^2$ = 6.45 $cm^2$

1 square foot = 0.0929 $m^2$ = 929 $cm^2$

## Volume

1 cubic inch = 16.4 $cm^3$

1 cubic foot = 28.3 $dm^3$

1 UK gallon = 4.55 l

1 US gallon = 3.79 l

## Mass

1 pound (lb) = 0.454 kg

1 ounce (oz) = 28.3 g

1 troy ounce = 31,7 g

1 short ton = 907 kg

## Spec. gr.

1 lb/$in^3$ = 27.7 t/$m^3$ = 27.7 g/$cm^3$

1 lb/$ft^3$ = 16.0 kg/$m^3$

## Force

1 kp (kgf) = 9.81 N

1 lbf = 4.45 N

## Energy

1 kWh = 3.60 MJ

1 kcal = 4.19 kJ

1 Btu = 1.06 kJ

## Power

1 kcal/h = 1.16 W

1 hp = 746 W (US)

1 hp = 736 W (metric)

## Pressure

1 bar = 14.5 psi = 100 kPa

1 bar = 100 kPa

1 kp/$cm^2$ = 98.1 kPa

1 atm = 760 torr = 101 kPa

1 lbf/$in^2$ (psi) = 6.89 kPa = 0.07031 kp/$cm^2$

1 torr (mm Hg) = 133 Pa

## Torque

1 ft. lb = 1.356 Nm

## Unit Area

1 sq.ft/t/24h = 2.23 $m^2$/(t h)

## Filtration capacity

1 lb/min/sq.ft = 293 kg/($m^2$ h)

1 lb/h/sq.ft = 4.882 kg/($m^2$ h)

## Surface load

1 usgpd/sq.ft = 1.698 x $10^{-3}$ $m^3$/($m^2$h)

1 usgph/sq.ft = 0.041 $m^3$/($m^2$ h)

1 usgpm/sq.ft = 2.44 $m^3$/($m^2$ h)

1 cfm/sq.ft = 0.3048 $m^3$/($m^2$ min)

## Flow

1 usgpm = 0.23 $m^3$/h

## Velocity

1 fpm = 18.288 m/h

ppm = parts per million = mg/l

ppb = parts per billion = mg/$m^3$

SS = suspended solids

TS = total solids (incl. dissolved solids)

## *Tyler standard scale*

| mesh | micron | mesh | micron | mesh | micron |
|---|---|---|---|---|---|
| $2^1/_2$ | 8 000 | 14 | 1 180 | 80 | 180 |
| 3 | 6 700 | 16 | 1 000 | 100 | 150 |
| $3^1/_2$ | 5 600 | 20 | 850 | 115 | 125 |
| 4 | 4 750 | 24 | 710 | 150 | 106 |
| 5 | 4 000 | 28 | 600 | 170 | 90 |
| 6 | 3 350 | 32 | 500 | 200 | 75 |
| 7 | 2 800 | 35 | 425 | 250 | 63 |
| 8 | 2 360 | 42 | 355 | 270 | 53 |
| 9 | 2 000 | 48 | 300 | 325 | 45 |
| 10 | 1 700 | 60 | 250 | 400 | 38 |
| 12 | 1 400 | 65 | 212 | 500 | 25 |

## *Specific gravity*

| Mineral | Density |
|---|---|
| **A** | |
| Albite | 2.6 |
| Almandine | 4.3 |
| Anatase | 3.9 |
| Andradite | 3.8 |
| Apatite | 3.2 |
| Arsenopyrite | 5.9 - 6.2 |
| Asbestos | 2.4 - 2.5 |
| Azurite | 3.8 |
| **B** | |
| Baddeleyite | 5.6 |
| Barite | 4.5 |
| Bauxite | 2.6 |
| Beryl | 2.7 - 2.8 |
| Biotite | 3.0 - 3.1 |
| Bismuth | 9.8 |
| **C** | |
| Calcite | 2.7 |
| Cassiterite | 7.0 |
| Celestite | 4.0 |
| Cerussite | 6.6 |
| Chalcocite | 5.5 - 5.8 |
| Chalcopyrite | 4.1 - 4.3 |
| Chlorite | 2.6 - 3.2 |
| Chromite | 5.1 |
| Crysocolla | 2.0 - 2.3 |
| Cinnabar | 8.1 |
| Cobaltite | 6.0 - 6.3 |
| Coemanite | 2.4 |
| Copper | 8.9 |
| Corundum | 3.9 - 4.1 |
| Covellite | 4.7 |
| Cryolite | 3.0 |
| Cuprite | 5.8 - 6.2 |
| **D** | |
| Diamond | 3.5 |
| Diopside | 3.3 - 3.4 |
| Dolomite | 1.8 - 2.9 |
| **E** | |
| Epidote | 3.4 |

| Mineral | Density |
|---|---|
| **F** | |
| Feldspar Group | 2.6 - 2.8 |
| Ferberite | 7.5 |
| Flint | 2.6 |
| Fluorite | 3.2 |
| Franklinite | 5.1 - 5.2 |
| **G** | |
| Gahnite | 4.6 |
| Galena | 7.5 |
| Goethite | 4.3 |
| Gold | 15.6 - 19.3 |
| Graphite | 2.1 - 2.2 |
| Grossularite | 3.5 |
| Gypsum | 2.3 |
| **H** | |
| Halite | 2.5 |
| Hematite | 5.2 |
| Hornblende | 3.1 - 3.3 |
| Huebnerite | 6.7 - 7.5 |
| Hypersthene | 3.4 |
| **I** | |
| Ilmenite | 4.7 |
| **K** | |
| Kaolinite | 2.6 |
| Kyanite | 3.6 - 3.7 |
| **L** | |
| Lepidolite | 2.8 - 2.9 |
| Limonite | 2.2 - 2.4 |
| **M** | |
| Magnesite | 3.0 |
| Magnetite | 4.7 |
| Malachite | 4.0 |
| Magnite | 4.3 |
| Marcasite | 4.6 - 4.9 |
| Martite | 5.2 |
| Microline | 2.6 |
| Microlite | 5.5 |
| Molybdenite | 4.7 - 5.0 |
| Monazite | 4.9 - 5.5 |
| Mullite | 3.2 |
| Muscovite | 2.8 - 3.0 |

| Mineral | Density |
|---|---|
| **N** | |
| Nepheline Syenite | 2.6 |
| Niccolite | 7.6 - 7.8 |
| **O** | |
| Olivine | 3.3 - 3.5 |
| Orpiment | 3.4 - 3.5 |
| Orthoclase | 2.5 - 2.6 |
| **P** | |
| Petalite | 2.4 |
| Platinum | 14.0 - 21.5 |
| Pyrite | 5.0 |
| Pyrochlore | 4.2 - 4.4 |
| Pyrolusite | 4.7 - 5.0 |
| Pyroxene | 3.1 - 3.6 |
| Pyrrhotite | 4.6 - 4.7 |
| **Q** | |
| Quartz | 2.7 |
| **R** | |
| Realgar | 3.6 |
| Rhodochrosite | 3.7 |
| Rhodonite | 3.6 - 3.7 |
| Rutile | 4.2 - 4.3 |
| **S** | |
| Scheelite | 6.1 |
| Serpentine | 2.5 - 2.7 |
| Siderite | 3.9 |
| Sillimanite | 3.2 |
| Silver | 10.1 - 11.1 |
| Smithsonite | 4.1 - 4.5 |
| Sphalerite | 3.9 - 4.0 |
| Sphene | 3.3 - 8.6 |
| Spinel | 3.6 |
| Spodumene | 3.1 - 3.2 |
| Stannite | 4.3 - 4.5 |
| Stibnite (Antimonite) | 4.6 |
| Sulphur | 2.1 |
| Sylvite | 2.0 |
| **T** | |
| Talc | 2.7 - 2.8 |
| Tantalite | 5.2 - 8.2 |
| Tetrahedrite | 5.0 |
| Thorite | 4.5 - 5.4 |
| Topaz | 3.5 - 3.6 |
| Tourmaline | 2.9 - 3.2 |
| **U** | |
| Uraninite | 11.0 |
| **V** | |
| Vermiculite | 2.4 - 2.7 |
| **W** | |
| Wolframite | 6.7 - 7.5 |
| Wollastonite | 2.8 - 2.9 |
| **Z** | |
| Zeolite | 2.0 - 2.5 |
| Zincite | 5.7 |
| Zircon | 4.7 |
| **Other solids of varying composition:** | |
| Slag | 1.5 - 4 |
| Soil | 1.5 - 2.8 |
| Ash (fly) | 1.5 - 3.5 |
| Ash (bottom) | 1.5 - 3 |
| Wet scrubber effluent | 2 - 5 |
| Mill scale | 4.9 - 5.2 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 1.4**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.003 | 99.714 | 41 | 1.133 | 2.153 |
| 2 | 1.006 | 49.714 | 42 | 1.136 | 2.095 |
| 3 | 1.009 | 33.048 | 43 | 1.140 | 2.040 |
| 4 | 1.012 | 24.714 | 44 | 1.144 | 1.987 |
| 5 | 1.014 | 19.714 | 45 | 1.148 | 1.937 |
| 6 | 1.017 | 16.381 | 46 | 1.151 | 1.888 |
| 7 | 1.020 | 14.000 | 47 | 1.155 | 1.842 |
| 8 | 1.023 | 12.214 | 48 | 1.159 | 1.798 |
| 9 | 1.026 | 10.825 | 49 | 1.163 | 1.755 |
| 10 | 1.029 | 9.714 | 50 | 1.167 | 1.714 |
| 11 | 1.032 | 8.805 | 51 | 1.171 | 1.675 |
| 12 | 1.036 | 8.048 | 52 | 1.174 | 1.637 |
| 13 | 1.039 | 7.407 | 53 | 1.178 | 1.601 |
| 14 | 1.042 | 6.857 | 54 | 1.182 | 1.566 |
| 15 | 1.045 | 6.381 | 55 | 1.186 | 1.532 |
| 16 | 1.048 | 5.964 | 56 | 1.190 | 1.500 |
| 17 | 1.051 | 5.597 | 57 | 1.195 | 1.469 |
| 18 | 1.054 | 5.270 | 58 | 1.199 | 1.438 |
| 19 | 1.057 | 4.977 | 59 | 1.203 | 1.409 |
| 20 | 1.061 | 4.714 | 60 | 1.207 | 1.381 |
| 21 | 1.064 | 4.476 | 61 | 1.211 | 1.354 |
| 22 | 1.067 | 4.260 | 62 | 1.215 | 1.327 |
| 23 | 1.070 | 4.062 | 63 | 1.220 | 1.302 |
| 24 | 1.074 | 3.881 | 64 | 1.224 | 1.277 |
| 25 | 1.077 | 3.714 | 65 | 1.228 | 1.253 |
| 26 | 1.080 | 3.560 | 66 | 1.232 | 1.229 |
| 27 | 1.084 | 3.418 | 67 | 1.237 | 1.207 |
| 28 | 1.087 | 3.286 | 68 | 1.241 | 1.185 |
| 29 | 1.090 | 3.163 | 69 | 1.246 | 1.164 |
| 30 | 1.094 | 3.048 | 70 | 1.250 | 1.143 |
| 31 | 1.097 | 2.940 | 71 | 1.254 | 1.123 |
| 32 | 1.101 | 2.839 | 72 | 1.259 | 1.103 |
| 33 | 1.104 | 2.745 | 73 | 1.264 | 1.084 |
| 34 | 1.108 | 2.655 | 74 | 1.268 | 1.066 |
| 35 | 1.111 | 2.571 | 75 | 1.273 | 1.048 |
| 36 | 1.115 | 2.492 | 76 | 1.277 | 1.030 |
| 37 | 1.118 | 2.417 | 77 | 1.282 | 1.013 |
| 38 | 1.122 | 2.346 | 78 | 1.287 | 0.996 |
| 39 | 1.125 | 2.278 | 79 | 1.292 | 0.980 |
| 40 | 1.129 | 2.214 | 80 | 1.296 | 0.964 |

**Density of solids: 1.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.004 | 99.556 | 41 | 1.223 | 1.995 |
| 2 | 1.009 | 49.556 | 42 | 1.230 | 1.937 |
| 3 | 1.014 | 32.889 | 43 | 1.236 | 1.881 |
| 4 | 1.018 | 24.556 | 44 | 1.243 | 1.828 |
| 5 | 1.023 | 19.556 | 45 | 1.250 | 1.778 |
| 6 | 1.027 | 16.222 | 46 | 1.257 | 1.729 |
| 7 | 1.032 | 13.841 | 47 | 1.264 | 1.683 |
| 8 | 1.037 | 12.056 | 48 | 1.271 | 1.639 |
| 9 | 1.042 | 10.667 | 49 | 1.278 | 1.596 |
| 10 | 1.047 | 9.556 | 50 | 1.286 | 1.556 |
| 11 | 1.051 | 8.646 | 51 | 1.293 | 1.516 |
| 12 | 1.056 | 7.889 | 52 | 1.301 | 1.479 |
| 13 | 1.061 | 7.248 | 53 | 1.308 | 1.442 |
| 14 | 1.066 | 6.698 | 54 | 1.316 | 1.407 |
| 15 | 1.071 | 6.222 | 55 | 1.324 | 1.374 |
| 16 | 1.077 | 5.806 | 56 | 1.331 | 1.341 |
| 17 | 1.082 | 5.438 | 57 | 1.339 | 1.310 |
| 18 | 1.087 | 5.111 | 58 | 1.347 | 1.280 |
| 19 | 1.092 | 4.819 | 59 | 1.355 | 1.250 |
| 20 | 1.098 | 4.556 | 60 | 1.364 | 1.222 |
| 21 | 1.103 | 4.317 | 61 | 1.372 | 1.195 |
| 22 | 1.108 | 4.101 | 62 | 1.380 | 1.168 |
| 23 | 1.114 | 3.903 | 63 | 1.389 | 1.143 |
| 24 | 1.119 | 3.722 | 64 | 1.398 | 1.118 |
| 25 | 1.125 | 3.556 | 65 | 1.406 | 1.094 |
| 26 | 1.131 | 3.402 | 66 | 1.415 | 1.071 |
| 27 | 1.136 | 3.259 | 67 | 1.424 | 1.048 |
| 28 | 1.142 | 3.127 | 68 | 1.433 | 1.026 |
| 29 | 1.148 | 3.004 | 69 | 1.442 | 1.005 |
| 30 | 1.154 | 2.889 | 70 | 1.452 | 0.984 |
| 31 | 1.160 | 2.781 | 71 | 1.461 | 0.964 |
| 32 | 1.166 | 2.681 | 72 | 1.471 | 0.944 |
| 33 | 1.172 | 2.586 | 73 | 1.480 | 0.925 |
| 34 | 1.178 | 2.497 | 74 | 1.490 | 0.907 |
| 35 | 1.184 | 2.413 | 75 | 1.500 | 0.889 |
| 36 | 1.190 | 2.333 | 76 | 1.510 | 0.871 |
| 37 | 1.197 | 2.258 | 77 | 1.520 | 0.854 |
| 38 | 1.203 | 2.187 | 78 | 1.531 | 0.838 |
| 39 | 1.210 | 2.120 | 79 | 1.541 | 0.821 |
| 40 | 1.216 | 2.056 | 80 | 1.552 | 0.806 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 1.4**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.003 | 23897 | 41 | 1.133 | 516 |
| 2 | 1.006 | 11914 | 42 | 1.136 | 502 |
| 3 | 1.009 | 7920 | 43 | 1.140 | 489 |
| 4 | 1.012 | 5923 | 44 | 1.144 | 476 |
| 5 | 1.014 | 4725 | 45 | 1.148 | 464 |
| 6 | 1.017 | 3926 | 46 | 1.151 | 452 |
| 7 | 1.020 | 3355 | 47 | 1.155 | 441 |
| 8 | 1.023 | 2927 | 48 | 1.159 | 431 |
| 9 | 1.026 | 2594 | 49 | 1.163 | 421 |
| 10 | 1.029 | 2328 | 50 | 1.167 | 411 |
| 11 | 1.032 | 2110 | 51 | 1.171 | 401 |
| 12 | 1.036 | 1929 | 52 | 1.174 | 392 |
| 13 | 1.039 | 1775 | 53 | 1.178 | 384 |
| 14 | 1.042 | 1643 | 54 | 1.182 | 375 |
| 15 | 1.045 | 1529 | 55 | 1.186 | 367 |
| 16 | 1.048 | 1429 | 56 | 1.190 | 359 |
| 17 | 1.051 | 1341 | 57 | 1.195 | 352 |
| 18 | 1.054 | 1263 | 58 | 1.199 | 345 |
| 19 | 1.057 | 1193 | 59 | 1.203 | 338 |
| 20 | 1.061 | 1130 | 60 | 1.207 | 331 |
| 21 | 1.064 | 1073 | 61 | 1.211 | 324 |
| 22 | 1.067 | 1021 | 62 | 1.215 | 318 |
| 23 | 1.070 | 973 | 63 | 1.220 | 312 |
| 24 | 1.074 | 930 | 64 | 1.224 | 306 |
| 25 | 1.077 | 890 | 65 | 1.228 | 300 |
| 26 | 1.080 | 853 | 66 | 1.232 | 295 |
| 27 | 1.084 | 819 | 67 | 1.237 | 289 |
| 28 | 1.087 | 787 | 68 | 1.241 | 284 |
| 29 | 1.090 | 758 | 69 | 1.246 | 279 |
| 30 | 1.094 | 730 | 70 | 1.250 | 274 |
| 31 | 1.097 | 705 | 71 | 1.254 | 269 |
| 32 | 1.101 | 680 | 72 | 1.259 | 264 |
| 33 | 1.104 | 658 | 73 | 1.264 | 260 |
| 34 | 1.108 | 636 | 74 | 1.268 | 255 |
| 35 | 1.111 | 616 | 75 | 1.273 | 251 |
| 36 | 1.115 | 597 | 76 | 1.277 | 247 |
| 37 | 1.118 | 579 | 77 | 1.282 | 243 |
| 38 | 1.122 | 562 | 78 | 1.287 | 239 |
| 39 | 1.125 | 546 | 79 | 1.292 | 235 |
| 40 | 1.129 | 531 | 80 | 1.296 | 231 |

**Density of solids: 1.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.004 | 23859 | 41 | 1.223 | 478 |
| 2 | 1.009 | 11876 | 42 | 1.230 | 464 |
| 3 | 1.014 | 7882 | 43 | 1.236 | 451 |
| 4 | 1.018 | 5885 | 44 | 1.243 | 438 |
| 5 | 1.023 | 4687 | 45 | 1.250 | 426 |
| 6 | 1.027 | 3888 | 46 | 1.257 | 414 |
| 7 | 1.032 | 3317 | 47 | 1.264 | 403 |
| 8 | 1.037 | 2889 | 48 | 1.271 | 393 |
| 9 | 1.042 | 2556 | 49 | 1.278 | 382 |
| 10 | 1.047 | 2290 | 50 | 1.286 | 373 |
| 11 | 1.051 | 2072 | 51 | 1.293 | 363 |
| 12 | 1.056 | 1891 | 52 | 1.301 | 354 |
| 13 | 1.061 | 1737 | 53 | 1.308 | 346 |
| 14 | 1.066 | 1605 | 54 | 1.316 | 337 |
| 15 | 1.071 | 1491 | 55 | 1.324 | 329 |
| 16 | 1.077 | 1391 | 56 | 1.331 | 321 |
| 17 | 1.082 | 1303 | 57 | 1.339 | 314 |
| 18 | 1.087 | 1225 | 58 | 1.347 | 307 |
| 19 | 1.092 | 1155 | 59 | 1.355 | 300 |
| 20 | 1.098 | 1092 | 60 | 1.364 | 293 |
| 21 | 1.103 | 1035 | 61 | 1.372 | 286 |
| 22 | 1.108 | 983 | 62 | 1.380 | 280 |
| 23 | 1.114 | 935 | 63 | 1.389 | 274 |
| 24 | 1.119 | 892 | 64 | 1.398 | 268 |
| 25 | 1.125 | 852 | 65 | 1.406 | 262 |
| 26 | 1.131 | 815 | 66 | 1.415 | 257 |
| 27 | 1.136 | 781 | 67 | 1.424 | 251 |
| 28 | 1.142 | 749 | 68 | 1.433 | 246 |
| 29 | 1.148 | 720 | 69 | 1.442 | 241 |
| 30 | 1.154 | 692 | 70 | 1.452 | 236 |
| 31 | 1.160 | 666 | 71 | 1.461 | 231 |
| 32 | 1.166 | 643 | 72 | 1.471 | 226 |
| 33 | 1.172 | 620 | 73 | 1.480 | 222 |
| 34 | 1.178 | 598 | 74 | 1.490 | 217 |
| 35 | 1.184 | 578 | 75 | 1.500 | 213 |
| 36 | 1.190 | 559 | 76 | 1.510 | 209 |
| 37 | 1.197 | 541 | 77 | 1.520 | 205 |
| 38 | 1.203 | 524 | 78 | 1.531 | 201 |
| 39 | 1.210 | 508 | 79 | 1.541 | 197 |
| 40 | 1.216 | 493 | 80 | 1.552 | 193 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 2.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.005 | 99.500 | 41 | 1.258 | 1.939 |
| 2 | 1.010 | 49.500 | 42 | 1.266 | 1.881 |
| 3 | 1.015 | 32.833 | 43 | 1.274 | 1.826 |
| 4 | 1.020 | 24.500 | 44 | 1.282 | 1.773 |
| 5 | 1.026 | 19.500 | 45 | 1.290 | 1.722 |
| 6 | 1.031 | 16.167 | 46 | 1.299 | 1.674 |
| 7 | 1.036 | 13.786 | 47 | 1.307 | 1.628 |
| 8 | 1.042 | 12.000 | 48 | 1.316 | 1.583 |
| 9 | 1.047 | 10.611 | 49 | 1.325 | 1.541 |
| 10 | 1.053 | 9.500 | 50 | 1.333 | 1.500 |
| 11 | 1.058 | 8.591 | 51 | 1.342 | 1.461 |
| 12 | 1.064 | 7.833 | 52 | 1.351 | 1.423 |
| 13 | 1.070 | 7.192 | 53 | 1.361 | 1.387 |
| 14 | 1.075 | 6.643 | 54 | 1.370 | 1.352 |
| 15 | 1.081 | 6.167 | 55 | 1.379 | 1.318 |
| 16 | 1.087 | 5.750 | 56 | 1.389 | 1.286 |
| 17 | 1.093 | 5.382 | 57 | 1.399 | 1.254 |
| 18 | 1.099 | 5.056 | 58 | 1.408 | 1.224 |
| 19 | 1.105 | 4.763 | 59 | 1.418 | 1.195 |
| 20 | 1.111 | 4.500 | 60 | 1.429 | 1.167 |
| 21 | 1.117 | 4.262 | 61 | 1.439 | 1.139 |
| 22 | 1.124 | 4.045 | 62 | 1.449 | 1.113 |
| 23 | 1.130 | 3.848 | 63 | 1.460 | 1.087 |
| 24 | 1.136 | 3.667 | 64 | 1.471 | 1.063 |
| 25 | 1.143 | 3.500 | 65 | 1.481 | 1.038 |
| 26 | 1.149 | 3.346 | 66 | 1.493 | 1.015 |
| 27 | 1.156 | 3.204 | 67 | 1.504 | 0.993 |
| 28 | 1.163 | 3.071 | 68 | 1.515 | 0.971 |
| 29 | 1.170 | 2.948 | 69 | 1.527 | 0.949 |
| 30 | 1.176 | 2.833 | 70 | 1.538 | 0.929 |
| 31 | 1.183 | 2.726 | 71 | 1.550 | 0.908 |
| 32 | 1.190 | 2.625 | 72 | 1.563 | 0.889 |
| 33 | 1.198 | 2.530 | 73 | 1.575 | 0.870 |
| 34 | 1.205 | 2.441 | 74 | 1.587 | 0.851 |
| 35 | 1.212 | 2.357 | 75 | 1.600 | 0.833 |
| 36 | 1.220 | 2.278 | 76 | 1.613 | 0.816 |
| 37 | 1.227 | 2.203 | 77 | 1.626 | 0.799 |
| 38 | 1.235 | 2.132 | 78 | 1.639 | 0.782 |
| 39 | 1.242 | 2.064 | 79 | 1.653 | 0.766 |
| 40 | 1.250 | 2.000 | 80 | 1.667 | 0.750 |

**Density of solids: 2.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.006 | 99.385 | 41 | 1.337 | 1.824 |
| 2 | 1.012 | 49.385 | 42 | 1.349 | 1.766 |
| 3 | 1.019 | 32.718 | 43 | 1.360 | 1.710 |
| 4 | 1.025 | 24.385 | 44 | 1.371 | 1.657 |
| 5 | 1.032 | 19.385 | 45 | 1.383 | 1.607 |
| 6 | 1.038 | 16.051 | 46 | 1.395 | 1.559 |
| 7 | 1.045 | 13.670 | 47 | 1.407 | 1.512 |
| 8 | 1.052 | 11.885 | 48 | 1.419 | 1.468 |
| 9 | 1.059 | 10.496 | 49 | 1.432 | 1.425 |
| 10 | 1.066 | 9.385 | 50 | 1.444 | 1.385 |
| 11 | 1.073 | 8.476 | 51 | 1.457 | 1.345 |
| 12 | 1.080 | 7.718 | 52 | 1.471 | 1.308 |
| 13 | 1.087 | 7.077 | 53 | 1.484 | 1.271 |
| 14 | 1.094 | 6.527 | 54 | 1.498 | 1.236 |
| 15 | 1.102 | 6.051 | 55 | 1.512 | 1.203 |
| 16 | 1.109 | 5.635 | 56 | 1.526 | 1.170 |
| 17 | 1.117 | 5.267 | 57 | 1.540 | 1.139 |
| 18 | 1.125 | 4.940 | 58 | 1.555 | 1.109 |
| 19 | 1.132 | 4.648 | 59 | 1.570 | 1.080 |
| 20 | 1.140 | 4.385 | 60 | 1.585 | 1.051 |
| 21 | 1.148 | 4.147 | 61 | 1.601 | 1.024 |
| 22 | 1.157 | 3.930 | 62 | 1.617 | 0.998 |
| 23 | 1.165 | 3.732 | 63 | 1.633 | 0.972 |
| 24 | 1.173 | 3.551 | 64 | 1.650 | 0.947 |
| 25 | 1.182 | 3.385 | 65 | 1.667 | 0.923 |
| 26 | 1.190 | 3.231 | 66 | 1.684 | 0.900 |
| 27 | 1.199 | 3.088 | 67 | 1.702 | 0.877 |
| 28 | 1.208 | 2.956 | 68 | 1.720 | 0.855 |
| 29 | 1.217 | 2.833 | 69 | 1.738 | 0.834 |
| 30 | 1.226 | 2.718 | 70 | 1.757 | 0.813 |
| 31 | 1.236 | 2.610 | 71 | 1.776 | 0.793 |
| 32 | 1.245 | 2.510 | 72 | 1.796 | 0.774 |
| 33 | 1.255 | 2.415 | 73 | 1.816 | 0.754 |
| 34 | 1.265 | 2.326 | 74 | 1.836 | 0.736 |
| 35 | 1.275 | 2.242 | 75 | 1.857 | 0.718 |
| 36 | 1.285 | 2.162 | 76 | 1.879 | 0.700 |
| 37 | 1.295 | 2.087 | 77 | 1.901 | 0.683 |
| 38 | 1.305 | 2.016 | 78 | 1.923 | 0.667 |
| 39 | 1.316 | 1.949 | 79 | 1.946 | 0.650 |
| 40 | 1.327 | 1.885 | 80 | 1.970 | 0.635 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 2.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.005 | 23845 | 41 | 1.258 | 465 |
| 2 | 1.010 | 11863 | 42 | 1.266 | 451 |
| 3 | 1.015 | 7869 | 43 | 1.274 | 438 |
| 4 | 1.020 | 5871 | 44 | 1.282 | 425 |
| 5 | 1.026 | 4673 | 45 | 1.290 | 413 |
| 6 | 1.031 | 3874 | 46 | 1.299 | 401 |
| 7 | 1.036 | 3304 | 47 | 1.307 | 390 |
| 8 | 1.042 | 2876 | 48 | 1.316 | 379 |
| 9 | 1.047 | 2543 | 49 | 1.325 | 369 |
| 10 | 1.053 | 2277 | 50 | 1.333 | 359 |
| 11 | 1.058 | 2059 | 51 | 1.342 | 350 |
| 12 | 1.064 | 1877 | 52 | 1.351 | 341 |
| 13 | 1.070 | 1724 | 53 | 1.361 | 332 |
| 14 | 1.075 | 1592 | 54 | 1.370 | 324 |
| 15 | 1.081 | 1478 | 55 | 1.379 | 316 |
| 16 | 1.087 | 1378 | 56 | 1.389 | 308 |
| 17 | 1.093 | 1290 | 57 | 1.399 | 301 |
| 18 | 1.099 | 1212 | 58 | 1.408 | 293 |
| 19 | 1.105 | 1141 | 59 | 1.418 | 286 |
| 20 | 1.111 | 1078 | 60 | 1.429 | 280 |
| 21 | 1.117 | 1021 | 61 | 1.439 | 273 |
| 22 | 1.124 | 969 | 62 | 1.449 | 267 |
| 23 | 1.130 | 922 | 63 | 1.460 | 261 |
| 24 | 1.136 | 879 | 64 | 1.471 | 255 |
| 25 | 1.143 | 839 | 65 | 1.481 | 249 |
| 26 | 1.149 | 802 | 66 | 1.493 | 243 |
| 27 | 1.156 | 768 | 67 | 1.504 | 238 |
| 28 | 1.163 | 736 | 68 | 1.515 | 233 |
| 29 | 1.170 | 706 | 69 | 1.527 | 227 |
| 30 | 1.176 | 679 | 70 | 1.538 | 223 |
| 31 | 1.183 | 653 | 71 | 1.550 | 218 |
| 32 | 1.190 | 629 | 72 | 1.563 | 213 |
| 33 | 1.198 | 606 | 73 | 1.575 | 208 |
| 34 | 1.205 | 585 | 74 | 1.587 | 204 |
| 35 | 1.212 | 565 | 75 | 1.600 | 200 |
| 36 | 1.220 | 546 | 76 | 1.613 | 196 |
| 37 | 1.227 | 528 | 77 | 1.626 | 191 |
| 38 | 1.235 | 511 | 78 | 1.639 | 187 |
| 39 | 1.242 | 495 | 79 | 1.653 | 184 |
| 40 | 1.250 | 479 | 80 | 1.667 | 180 |

**Density of solids: 2.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.006 | 23818 | 41 | 1.337 | 437 |
| 2 | 1.012 | 11835 | 42 | 1.349 | 423 |
| 3 | 1.019 | 7841 | 43 | 1.360 | 410 |
| 4 | 1.025 | 5844 | 44 | 1.371 | 397 |
| 5 | 1.032 | 4646 | 45 | 1.383 | 385 |
| 6 | 1.038 | 3847 | 46 | 1.395 | 374 |
| 7 | 1.045 | 3276 | 47 | 1.407 | 362 |
| 8 | 1.052 | 2848 | 48 | 1.419 | 352 |
| 9 | 1.059 | 2515 | 49 | 1.432 | 342 |
| 10 | 1.066 | 2249 | 50 | 1.444 | 332 |
| 11 | 1.073 | 2031 | 51 | 1.457 | 322 |
| 12 | 1.080 | 1850 | 52 | 1.471 | 313 |
| 13 | 1.087 | 1696 | 53 | 1.484 | 305 |
| 14 | 1.094 | 1564 | 54 | 1.498 | 296 |
| 15 | 1.102 | 1450 | 55 | 1.512 | 288 |
| 16 | 1.109 | 1350 | 56 | 1.526 | 280 |
| 17 | 1.117 | 1262 | 57 | 1.540 | 273 |
| 18 | 1.125 | 1184 | 58 | 1.555 | 266 |
| 19 | 1.132 | 1114 | 59 | 1.570 | 259 |
| 20 | 1.140 | 1051 | 60 | 1.585 | 252 |
| 21 | 1.148 | 994 | 61 | 1.601 | 245 |
| 22 | 1.157 | 942 | 62 | 1.617 | 239 |
| 23 | 1.165 | 894 | 63 | 1.633 | 233 |
| 24 | 1.173 | 851 | 64 | 1.650 | 227 |
| 25 | 1.182 | 811 | 65 | 1.667 | 221 |
| 26 | 1.190 | 774 | 66 | 1.684 | 216 |
| 27 | 1.199 | 740 | 67 | 1.702 | 210 |
| 28 | 1.208 | 708 | 68 | 1.720 | 205 |
| 29 | 1.217 | 679 | 69 | 1.738 | 200 |
| 30 | 1.226 | 651 | 70 | 1.757 | 195 |
| 31 | 1.236 | 625 | 71 | 1.776 | 190 |
| 32 | 1.245 | 602 | 72 | 1.796 | 185 |
| 33 | 1.255 | 579 | 73 | 1.816 | 181 |
| 34 | 1.265 | 557 | 74 | 1.836 | 176 |
| 35 | 1.275 | 537 | 75 | 1.857 | 172 |
| 36 | 1.285 | 518 | 76 | 1.879 | 168 |
| 37 | 1.295 | 500 | 77 | 1.901 | 164 |
| 38 | 1.305 | 483 | 78 | 1.923 | 160 |
| 39 | 1.316 | 467 | 79 | 1.946 | 156 |
| 40 | 1.327 | 452 | 80 | 1.970 | 152 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 2.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.006 | 99.357 | 41 | 1.358 | 1.796 |
| 2 | 1.013 | 49.357 | 42 | 1.370 | 1.738 |
| 3 | 1.020 | 32.690 | 43 | 1.382 | 1.683 |
| 4 | 1.026 | 24.357 | 44 | 1.394 | 1.630 |
| 5 | 1.033 | 19.357 | 45 | 1.407 | 1.579 |
| 6 | 1.040 | 16.024 | 46 | 1.420 | 1.531 |
| 7 | 1.047 | 13.643 | 47 | 1.433 | 1.485 |
| 8 | 1.054 | 11.857 | 48 | 1.446 | 1.440 |
| 9 | 1.061 | 10.468 | 49 | 1.460 | 1.398 |
| 10 | 1.069 | 9.357 | 50 | 1.474 | 1.357 |
| 11 | 1.076 | 8.448 | 51 | 1.488 | 1.318 |
| 12 | 1.084 | 7.690 | 52 | 1.502 | 1.280 |
| 13 | 1.091 | 7.049 | 53 | 1.517 | 1.244 |
| 14 | 1.099 | 6.500 | 54 | 1.532 | 1.209 |
| 15 | 1.107 | 6.024 | 55 | 1.547 | 1.175 |
| 16 | 1.115 | 5.607 | 56 | 1.563 | 1.143 |
| 17 | 1.123 | 5.239 | 57 | 1.578 | 1.112 |
| 18 | 1.131 | 4.913 | 58 | 1.595 | 1.081 |
| 19 | 1.139 | 4.620 | 59 | 1.611 | 1.052 |
| 20 | 1.148 | 4.357 | 60 | 1.628 | 1.024 |
| 21 | 1.156 | 4.119 | 61 | 1.645 | 0.996 |
| 22 | 1.165 | 3.903 | 62 | 1.663 | 0.970 |
| 23 | 1.174 | 3.705 | 63 | 1.681 | 0.944 |
| 24 | 1.182 | 3.524 | 64 | 1.699 | 0.920 |
| 25 | 1.191 | 3.357 | 65 | 1.718 | 0.896 |
| 26 | 1.201 | 3.203 | 66 | 1.737 | 0.872 |
| 27 | 1.210 | 3.061 | 67 | 1.757 | 0.850 |
| 28 | 1.220 | 2.929 | 68 | 1.777 | 0.828 |
| 29 | 1.229 | 2.805 | 69 | 1.797 | 0.806 |
| 30 | 1.239 | 2.690 | 70 | 1.818 | 0.786 |
| 31 | 1.249 | 2.583 | 71 | 1.840 | 0.766 |
| 32 | 1.259 | 2.482 | 72 | 1.862 | 0.746 |
| 33 | 1.269 | 2.387 | 73 | 1.884 | 0.727 |
| 34 | 1.280 | 2.298 | 74 | 1.907 | 0.708 |
| 35 | 1.290 | 2.214 | 75 | 1.931 | 0.690 |
| 36 | 1.301 | 2.135 | 76 | 1.955 | 0.673 |
| 37 | 1.312 | 2.060 | 77 | 1.980 | 0.656 |
| 38 | 1.323 | 1.989 | 78 | 2.006 | 0.639 |
| 39 | 1.335 | 1.921 | 79 | 2.032 | 0.623 |
| 40 | 1.346 | 1.857 | 80 | 2.059 | 0.607 |

**Density of solids: 3.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 99.333 | 41 | 1.376 | 1.772 |
| 2 | 1.014 | 49.333 | 42 | 1.389 | 1.714 |
| 3 | 1.020 | 32.667 | 43 | 1.402 | 1.659 |
| 4 | 1.027 | 24.333 | 44 | 1.415 | 1.606 |
| 5 | 1.034 | 19.333 | 45 | 1.429 | 1.556 |
| 6 | 1.042 | 16.000 | 46 | 1.442 | 1.507 |
| 7 | 1.049 | 13.619 | 47 | 1.456 | 1.461 |
| 8 | 1.056 | 11.833 | 48 | 1.471 | 1.417 |
| 9 | 1.064 | 10.444 | 49 | 1.485 | 1.374 |
| 10 | 1.071 | 9.333 | 50 | 1.500 | 1.333 |
| 11 | 1.079 | 8.424 | 51 | 1.515 | 1.294 |
| 12 | 1.087 | 7.667 | 52 | 1.531 | 1.256 |
| 13 | 1.095 | 7.026 | 53 | 1.546 | 1.220 |
| 14 | 1.103 | 6.476 | 54 | 1.563 | 1.185 |
| 15 | 1.111 | 6.000 | 55 | 1.579 | 1.152 |
| 16 | 1.119 | 5.583 | 56 | 1.596 | 1.119 |
| 17 | 1.128 | 5.216 | 57 | 1.613 | 1.088 |
| 18 | 1.136 | 4.889 | 58 | 1.630 | 1.057 |
| 19 | 1.145 | 4.596 | 59 | 1.648 | 1.028 |
| 20 | 1.154 | 4.333 | 60 | 1.667 | 1.000 |
| 21 | 1.163 | 4.095 | 61 | 1.685 | 0.973 |
| 22 | 1.172 | 3.879 | 62 | 1.705 | 0.946 |
| 23 | 1.181 | 3.681 | 63 | 1.724 | 0.921 |
| 24 | 1.190 | 3.500 | 64 | 1.744 | 0.896 |
| 25 | 1.200 | 3.333 | 65 | 1.765 | 0.872 |
| 26 | 1.210 | 3.179 | 66 | 1.786 | 0.848 |
| 27 | 1.220 | 3.037 | 67 | 1.807 | 0.826 |
| 28 | 1.230 | 2.905 | 68 | 1.829 | 0.804 |
| 29 | 1.240 | 2.782 | 69 | 1.852 | 0.783 |
| 30 | 1.250 | 2.667 | 70 | 1.875 | 0.762 |
| 31 | 1.261 | 2.559 | 71 | 1.899 | 0.742 |
| 32 | 1.271 | 2.458 | 72 | 1.923 | 0.722 |
| 33 | 1.282 | 2.364 | 73 | 1.948 | 0.703 |
| 34 | 1.293 | 2.275 | 74 | 1.974 | 0.685 |
| 35 | 1.304 | 2.190 | 75 | 2.000 | 0.667 |
| 36 | 1.316 | 2.111 | 76 | 2.027 | 0.649 |
| 37 | 1.327 | 2.036 | 77 | 2.055 | 0.632 |
| 38 | 1.339 | 1.965 | 78 | 2.083 | 0.615 |
| 39 | 1.351 | 1.897 | 79 | 2.113 | 0.599 |
| 40 | 1.364 | 1.833 | 80 | 2.143 | 0.583 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 2.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.006 | 23811 | 41 | 1.358 | 430 |
| 2 | 1.013 | 11829 | 42 | 1.370 | 417 |
| 3 | 1.020 | 7834 | 43 | 1.382 | 403 |
| 4 | 1.026 | 5837 | 44 | 1.394 | 391 |
| 5 | 1.033 | 4639 | 45 | 1.407 | 378 |
| 6 | 1.040 | 3840 | 46 | 1.420 | 367 |
| 7 | 1.047 | 3270 | 47 | 1.433 | 356 |
| 8 | 1.054 | 2842 | 48 | 1.446 | 345 |
| 9 | 1.061 | 2509 | 49 | 1.460 | 335 |
| 10 | 1.069 | 2242 | 50 | 1.474 | 325 |
| 11 | 1.076 | 2025 | 51 | 1.488 | 316 |
| 12 | 1.084 | 1843 | 52 | 1.502 | 307 |
| 13 | 1.091 | 1689 | 53 | 1.517 | 298 |
| 14 | 1.099 | 1558 | 54 | 1.532 | 290 |
| 15 | 1.107 | 1444 | 55 | 1.547 | 282 |
| 16 | 1.115 | 1344 | 56 | 1.563 | 274 |
| 17 | 1.123 | 1256 | 57 | 1.578 | 266 |
| 18 | 1.131 | 1177 | 58 | 1.595 | 259 |
| 19 | 1.139 | 1107 | 59 | 1.611 | 252 |
| 20 | 1.148 | 1044 | 60 | 1.628 | 245 |
| 21 | 1.156 | 987 | 61 | 1.645 | 239 |
| 22 | 1.165 | 935 | 62 | 1.663 | 232 |
| 23 | 1.174 | 888 | 63 | 1.681 | 226 |
| 24 | 1.182 | 845 | 64 | 1.699 | 220 |
| 25 | 1.191 | 805 | 65 | 1.718 | 215 |
| 26 | 1.201 | 768 | 66 | 1.737 | 209 |
| 27 | 1.210 | 734 | 67 | 1.757 | 204 |
| 28 | 1.220 | 702 | 68 | 1.777 | 198 |
| 29 | 1.229 | 672 | 69 | 1.797 | 193 |
| 30 | 1.239 | 645 | 70 | 1.818 | 188 |
| 31 | 1.249 | 619 | 71 | 1.840 | 184 |
| 32 | 1.259 | 595 | 72 | 1.862 | 179 |
| 33 | 1.269 | 572 | 73 | 1.884 | 174 |
| 34 | 1.280 | 551 | 74 | 1.907 | 170 |
| 35 | 1.290 | 531 | 75 | 1.931 | 165 |
| 36 | 1.301 | 512 | 76 | 1.955 | 161 |
| 37 | 1.312 | 494 | 77 | 1.980 | 157 |
| 38 | 1.323 | 477 | 78 | 2.006 | 153 |
| 39 | 1.335 | 460 | 79 | 2.032 | 149 |
| 40 | 1.346 | 445 | 80 | 2.059 | 145 |

**Density of solids: 3.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 23805 | 41 | 1.376 | 425 |
| 2 | 1.014 | 11823 | 42 | 1.389 | 411 |
| 3 | 1.020 | 7829 | 43 | 1.402 | 398 |
| 4 | 1.027 | 5831 | 44 | 1.415 | 385 |
| 5 | 1.034 | 4633 | 45 | 1.429 | 373 |
| 6 | 1.042 | 3834 | 46 | 1.442 | 361 |
| 7 | 1.049 | 3264 | 47 | 1.456 | 350 |
| 8 | 1.056 | 2836 | 48 | 1.471 | 340 |
| 9 | 1.064 | 2503 | 49 | 1.485 | 329 |
| 10 | 1.071 | 2237 | 50 | 1.500 | 319 |
| 11 | 1.079 | 2019 | 51 | 1.515 | 310 |
| 12 | 1.087 | 1837 | 52 | 1.531 | 301 |
| 13 | 1.095 | 1684 | 53 | 1.546 | 292 |
| 14 | 1.103 | 1552 | 54 | 1.563 | 284 |
| 15 | 1.111 | 1438 | 55 | 1.579 | 276 |
| 16 | 1.119 | 1338 | 56 | 1.596 | 268 |
| 17 | 1.128 | 1250 | 57 | 1.613 | 261 |
| 18 | 1.136 | 1172 | 58 | 1.630 | 253 |
| 19 | 1.145 | 1101 | 59 | 1.648 | 246 |
| 20 | 1.154 | 1038 | 60 | 1.667 | 240 |
| 21 | 1.163 | 981 | 61 | 1.685 | 233 |
| 22 | 1.172 | 930 | 62 | 1.705 | 227 |
| 23 | 1.181 | 882 | 63 | 1.724 | 221 |
| 24 | 1.190 | 839 | 64 | 1.744 | 215 |
| 25 | 1.200 | 799 | 65 | 1.765 | 209 |
| 26 | 1.210 | 762 | 66 | 1.786 | 203 |
| 27 | 1.220 | 728 | 67 | 1.807 | 198 |
| 28 | 1.230 | 696 | 68 | 1.829 | 193 |
| 29 | 1.240 | 667 | 69 | 1.852 | 188 |
| 30 | 1.250 | 639 | 70 | 1.875 | 183 |
| 31 | 1.261 | 613 | 71 | 1.899 | 178 |
| 32 | 1.271 | 589 | 72 | 1.923 | 173 |
| 33 | 1.282 | 567 | 73 | 1.948 | 168 |
| 34 | 1.293 | 545 | 74 | 1.974 | 164 |
| 35 | 1.304 | 525 | 75 | 2.000 | 160 |
| 36 | 1.316 | 506 | 76 | 2.027 | 156 |
| 37 | 1.327 | 488 | 77 | 2.055 | 151 |
| 38 | 1.339 | 471 | 78 | 2.083 | 147 |
| 39 | 1.351 | 455 | 79 | 2.113 | 144 |
| 40 | 1.364 | 439 | 80 | 2.143 | 140 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/m$^3$]
C = Pulp volume [m$^3$/ton solids]

**Density of solids: 3.2**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 99.313 | 41 | 1.393 | 1.752 |
| 2 | 1.014 | 49.313 | 42 | 1.406 | 1.693 |
| 3 | 1.021 | 32.646 | 43 | 1.420 | 1.638 |
| 4 | 1.028 | 24.313 | 44 | 1.434 | 1.585 |
| 5 | 1.036 | 19.313 | 45 | 1.448 | 1.535 |
| 6 | 1.043 | 15.979 | 46 | 1.463 | 1.486 |
| 7 | 1.051 | 13.598 | 47 | 1.477 | 1.440 |
| 8 | 1.058 | 11.813 | 48 | 1.493 | 1.396 |
| 9 | 1.066 | 10.424 | 49 | 1.508 | 1.353 |
| 10 | 1.074 | 9.313 | 50 | 1.524 | 1.313 |
| 11 | 1.082 | 8.403 | 51 | 1.540 | 1.273 |
| 12 | 1.090 | 7.646 | 52 | 1.556 | 1.236 |
| 13 | 1.098 | 7.005 | 53 | 1.573 | 1.199 |
| 14 | 1.107 | 6.455 | 54 | 1.590 | 1.164 |
| 15 | 1.115 | 5.979 | 55 | 1.608 | 1.131 |
| 16 | 1.124 | 5.563 | 56 | 1.626 | 1.098 |
| 17 | 1.132 | 5.195 | 57 | 1.644 | 1.067 |
| 18 | 1.141 | 4.868 | 58 | 1.663 | 1.037 |
| 19 | 1.150 | 4.576 | 59 | 1.682 | 1.007 |
| 20 | 1.159 | 4.313 | 60 | 1.702 | 0.979 |
| 21 | 1.169 | 4.074 | 61 | 1.722 | 0.952 |
| 22 | 1.178 | 3.858 | 62 | 1.743 | 0.925 |
| 23 | 1.188 | 3.660 | 63 | 1.764 | 0.900 |
| 24 | 1.198 | 3.479 | 64 | 1.786 | 0.875 |
| 25 | 1.208 | 3.313 | 65 | 1.808 | 0.851 |
| 26 | 1.218 | 3.159 | 66 | 1.831 | 0.828 |
| 27 | 1.228 | 3.016 | 67 | 1.854 | 0.805 |
| 28 | 1.238 | 2.884 | 68 | 1.878 | 0.783 |
| 29 | 1.249 | 2.761 | 69 | 1.902 | 0.762 |
| 30 | 1.260 | 2.646 | 70 | 1.928 | 0.741 |
| 31 | 1.271 | 2.538 | 71 | 1.954 | 0.721 |
| 32 | 1.282 | 2.438 | 72 | 1.980 | 0.701 |
| 33 | 1.293 | 2.343 | 73 | 2.008 | 0.682 |
| 34 | 1.305 | 2.254 | 74 | 2.036 | 0.664 |
| 35 | 1.317 | 2.170 | 75 | 2.065 | 0.646 |
| 36 | 1.329 | 2.090 | 76 | 2.094 | 0.628 |
| 37 | 1.341 | 2.015 | 77 | 2.125 | 0.611 |
| 38 | 1.354 | 1.944 | 78 | 2.156 | 0.595 |
| 39 | 1.366 | 1.877 | 79 | 2.189 | 0.578 |
| 40 | 1.379 | 1.813 | 80 | 2.222 | 0.563 |

**Density of solids: 3.4**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 99.294 | 41 | 1.407 | 1.733 |
| 2 | 1.014 | 49.294 | 42 | 1.421 | 1.675 |
| 3 | 1.022 | 32.627 | 43 | 1.436 | 1.620 |
| 4 | 1.029 | 24.294 | 44 | 1.451 | 1.567 |
| 5 | 1.037 | 19.294 | 45 | 1.466 | 1.516 |
| 6 | 1.044 | 15.961 | 46 | 1.481 | 1.468 |
| 7 | 1.052 | 13.580 | 47 | 1.496 | 1.422 |
| 8 | 1.060 | 11.794 | 48 | 1.512 | 1.377 |
| 9 | 1.068 | 10.405 | 49 | 1.529 | 1.335 |
| 10 | 1.076 | 9.294 | 50 | 1.545 | 1.294 |
| 11 | 1.084 | 8.385 | 51 | 1.563 | 1.255 |
| 12 | 1.093 | 7.627 | 52 | 1.580 | 1.217 |
| 13 | 1.101 | 6.986 | 53 | 1.598 | 1.181 |
| 14 | 1.110 | 6.437 | 54 | 1.616 | 1.146 |
| 15 | 1.118 | 5.961 | 55 | 1.635 | 1.112 |
| 16 | 1.127 | 5.544 | 56 | 1.654 | 1.080 |
| 17 | 1.136 | 5.176 | 57 | 1.673 | 1.049 |
| 18 | 1.146 | 4.850 | 58 | 1.693 | 1.018 |
| 19 | 1.155 | 4.557 | 59 | 1.714 | 0.989 |
| 20 | 1.164 | 4.294 | 60 | 1.735 | 0.961 |
| 21 | 1.174 | 4.056 | 61 | 1.756 | 0.933 |
| 22 | 1.184 | 3.840 | 62 | 1.778 | 0.907 |
| 23 | 1.194 | 3.642 | 63 | 1.801 | 0.881 |
| 24 | 1.204 | 3.461 | 64 | 1.824 | 0.857 |
| 25 | 1.214 | 3.294 | 65 | 1.848 | 0.833 |
| 26 | 1.225 | 3.140 | 66 | 1.872 | 0.809 |
| 27 | 1.235 | 2.998 | 67 | 1.897 | 0.787 |
| 28 | 1.246 | 2.866 | 68 | 1.923 | 0.765 |
| 29 | 1.257 | 2.742 | 69 | 1.950 | 0.743 |
| 30 | 1.269 | 2.627 | 70 | 1.977 | 0.723 |
| 31 | 1.280 | 2.520 | 71 | 2.005 | 0.703 |
| 32 | 1.292 | 2.419 | 72 | 2.033 | 0.683 |
| 33 | 1.304 | 2.324 | 73 | 2.063 | 0.664 |
| 34 | 1.316 | 2.235 | 74 | 2.094 | 0.645 |
| 35 | 1.328 | 2.151 | 75 | 2.125 | 0.627 |
| 36 | 1.341 | 2.072 | 76 | 2.157 | 0.610 |
| 37 | 1.354 | 1.997 | 77 | 2.191 | 0.593 |
| 38 | 1.367 | 1.926 | 78 | 2.225 | 0.576 |
| 39 | 1.380 | 1.858 | 79 | 2.261 | 0.560 |
| 40 | 1.393 | 1.794 | 80 | 2.297 | 0.544 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 3.2**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 23801 | 41 | 1.393 | 420 |
| 2 | 1.014 | 11818 | 42 | 1.406 | 406 |
| 3 | 1.021 | 7824 | 43 | 1.420 | 393 |
| 4 | 1.028 | 5827 | 44 | 1.434 | 380 |
| 5 | 1.036 | 4628 | 45 | 1.448 | 368 |
| 6 | 1.043 | 3829 | 46 | 1.463 | 356 |
| 7 | 1.051 | 3259 | 47 | 1.477 | 345 |
| 8 | 1.058 | 2831 | 48 | 1.493 | 335 |
| 9 | 1.066 | 2498 | 49 | 1.508 | 324 |
| 10 | 1.074 | 2232 | 50 | 1.524 | 315 |
| 11 | 1.082 | 2014 | 51 | 1.540 | 305 |
| 12 | 1.090 | 1832 | 52 | 1.556 | 296 |
| 13 | 1.098 | 1679 | 53 | 1.573 | 287 |
| 14 | 1.107 | 1547 | 54 | 1.590 | 279 |
| 15 | 1.115 | 1433 | 55 | 1.608 | 271 |
| 16 | 1.124 | 1333 | 56 | 1.626 | 263 |
| 17 | 1.132 | 1245 | 57 | 1.644 | 256 |
| 18 | 1.141 | 1167 | 58 | 1.663 | 249 |
| 19 | 1.150 | 1097 | 59 | 1.682 | 241 |
| 20 | 1.159 | 1034 | 60 | 1.702 | 235 |
| 21 | 1.169 | 976 | 61 | 1.722 | 228 |
| 22 | 1.178 | 925 | 62 | 1.743 | 222 |
| 23 | 1.188 | 877 | 63 | 1.764 | 216 |
| 24 | 1.198 | 834 | 64 | 1.786 | 210 |
| 25 | 1.208 | 794 | 65 | 1.808 | 204 |
| 26 | 1.218 | 757 | 66 | 1.831 | 198 |
| 27 | 1.228 | 723 | 67 | 1.854 | 193 |
| 28 | 1.238 | 691 | 68 | 1.878 | 188 |
| 29 | 1.249 | 662 | 69 | 1.902 | 183 |
| 30 | 1.260 | 634 | 70 | 1.928 | 178 |
| 31 | 1.271 | 608 | 71 | 1.954 | 173 |
| 32 | 1.282 | 584 | 72 | 1.980 | 168 |
| 33 | 1.293 | 562 | 73 | 2.008 | 163 |
| 34 | 1.305 | 540 | 74 | 2.036 | 159 |
| 35 | 1.317 | 520 | 75 | 2.065 | 155 |
| 36 | 1.329 | 501 | 76 | 2.094 | 151 |
| 37 | 1.341 | 483 | 77 | 2.125 | 146 |
| 38 | 1.354 | 466 | 78 | 2.156 | 143 |
| 39 | 1.366 | 450 | 79 | 2.189 | 139 |
| 40 | 1.379 | 434 | 80 | 2.222 | 135 |

**Density of solids: 3.4**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 23796 | 41 | 1.407 | 415 |
| 2 | 1.014 | 11813 | 42 | 1.421 | 401 |
| 3 | 1.022 | 7819 | 43 | 1.436 | 388 |
| 4 | 1.029 | 5822 | 44 | 1.451 | 376 |
| 5 | 1.037 | 4624 | 45 | 1.466 | 363 |
| 6 | 1.044 | 3825 | 46 | 1.481 | 352 |
| 7 | 1.052 | 3254 | 47 | 1.496 | 341 |
| 8 | 1.060 | 2826 | 48 | 1.512 | 330 |
| 9 | 1.068 | 2494 | 49 | 1.529 | 320 |
| 10 | 1.076 | 2227 | 50 | 1.545 | 310 |
| 11 | 1.084 | 2009 | 51 | 1.563 | 301 |
| 12 | 1.093 | 1828 | 52 | 1.580 | 292 |
| 13 | 1.101 | 1674 | 53 | 1.598 | 283 |
| 14 | 1.110 | 1543 | 54 | 1.616 | 275 |
| 15 | 1.118 | 1429 | 55 | 1.635 | 266 |
| 16 | 1.127 | 1329 | 56 | 1.654 | 259 |
| 17 | 1.136 | 1240 | 57 | 1.673 | 251 |
| 18 | 1.146 | 1162 | 58 | 1.693 | 244 |
| 19 | 1.155 | 1092 | 59 | 1.714 | 237 |
| 20 | 1.164 | 1029 | 60 | 1.735 | 230 |
| 21 | 1.174 | 972 | 61 | 1.756 | 224 |
| 22 | 1.184 | 920 | 62 | 1.778 | 217 |
| 23 | 1.194 | 873 | 63 | 1.801 | 211 |
| 24 | 1.204 | 829 | 64 | 1.824 | 205 |
| 25 | 1.214 | 789 | 65 | 1.848 | 200 |
| 26 | 1.225 | 753 | 66 | 1.872 | 194 |
| 27 | 1.235 | 718 | 67 | 1.897 | 189 |
| 28 | 1.246 | 687 | 68 | 1.923 | 183 |
| 29 | 1.257 | 657 | 69 | 1.950 | 178 |
| 30 | 1.269 | 630 | 70 | 1.977 | 173 |
| 31 | 1.280 | 604 | 71 | 2.005 | 168 |
| 32 | 1.292 | 580 | 72 | 2.033 | 164 |
| 33 | 1.304 | 557 | 73 | 2.063 | 159 |
| 34 | 1.316 | 536 | 74 | 2.094 | 155 |
| 35 | 1.328 | 515 | 75 | 2.125 | 150 |
| 36 | 1.341 | 497 | 76 | 2.157 | 146 |
| 37 | 1.354 | 479 | 77 | 2.191 | 142 |
| 38 | 1.367 | 462 | 78 | 2.225 | 138 |
| 39 | 1.380 | 445 | 79 | 2.261 | 134 |
| 40 | 1.393 | 430 | 80 | 2.297 | 130 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 3.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 99.278 | 41 | 1.421 | 1.717 |
| 2 | 1.015 | 49.278 | 42 | 1.435 | 1.659 |
| 3 | 1.022 | 32.611 | 43 | 1.450 | 1.603 |
| 4 | 1.030 | 24.278 | 44 | 1.466 | 1.551 |
| 5 | 1.037 | 19.278 | 45 | 1.481 | 1.500 |
| 6 | 1.045 | 15.944 | 46 | 1.498 | 1.452 |
| 7 | 1.053 | 13.563 | 47 | 1.514 | 1.405 |
| 8 | 1.061 | 11.778 | 48 | 1.531 | 1.361 |
| 9 | 1.070 | 10.389 | 49 | 1.548 | 1.319 |
| 10 | 1.078 | 9.278 | 50 | 1.565 | 1.278 |
| 11 | 1.086 | 8.369 | 51 | 1.583 | 1.239 |
| 12 | 1.095 | 7.611 | 52 | 1.601 | 1.201 |
| 13 | 1.104 | 6.970 | 53 | 1.620 | 1.165 |
| 14 | 1.112 | 6.421 | 54 | 1.639 | 1.130 |
| 15 | 1.121 | 5.944 | 55 | 1.659 | 1.096 |
| 16 | 1.131 | 5.528 | 56 | 1.679 | 1.063 |
| 17 | 1.140 | 5.160 | 57 | 1.700 | 1.032 |
| 18 | 1.149 | 4.833 | 58 | 1.721 | 1.002 |
| 19 | 1.159 | 4.541 | 59 | 1.742 | 0.973 |
| 20 | 1.169 | 4.278 | 60 | 1.765 | 0.944 |
| 21 | 1.179 | 4.040 | 61 | 1.787 | 0.917 |
| 22 | 1.189 | 3.823 | 62 | 1.811 | 0.891 |
| 23 | 1.199 | 3.626 | 63 | 1.835 | 0.865 |
| 24 | 1.210 | 3.444 | 64 | 1.860 | 0.840 |
| 25 | 1.220 | 3.278 | 65 | 1.885 | 0.816 |
| 26 | 1.231 | 3.124 | 66 | 1.911 | 0.793 |
| 27 | 1.242 | 2.981 | 67 | 1.938 | 0.770 |
| 28 | 1.253 | 2.849 | 68 | 1.965 | 0.748 |
| 29 | 1.265 | 2.726 | 69 | 1.993 | 0.727 |
| 30 | 1.277 | 2.611 | 70 | 2.022 | 0.706 |
| 31 | 1.288 | 2.504 | 71 | 2.052 | 0.686 |
| 32 | 1.301 | 2.403 | 72 | 2.083 | 0.667 |
| 33 | 1.313 | 2.308 | 73 | 2.115 | 0.648 |
| 34 | 1.325 | 2.219 | 74 | 2.148 | 0.629 |
| 35 | 1.338 | 2.135 | 75 | 2.182 | 0.611 |
| 36 | 1.351 | 2.056 | 76 | 2.217 | 0.594 |
| 37 | 1.365 | 1.980 | 77 | 2.253 | 0.576 |
| 38 | 1.378 | 1.909 | 78 | 2.290 | 0.560 |
| 39 | 1.392 | 1.842 | 79 | 2.329 | 0.544 |
| 40 | 1.406 | 1.778 | 80 | 2.368 | 0.528 |

**Density of solids: 3.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 99.263 | 41 | 1.433 | 1.702 |
| 2 | 1.015 | 49.263 | 42 | 1.448 | 1.644 |
| 3 | 1.023 | 32.596 | 43 | 1.464 | 1.589 |
| 4 | 1.030 | 24.263 | 44 | 1.480 | 1.536 |
| 5 | 1.038 | 19.263 | 45 | 1.496 | 1.485 |
| 6 | 1.046 | 15.930 | 46 | 1.513 | 1.437 |
| 7 | 1.054 | 13.549 | 47 | 1.530 | 1.391 |
| 8 | 1.063 | 11.763 | 48 | 1.547 | 1.346 |
| 9 | 1.071 | 10.374 | 49 | 1.565 | 1.304 |
| 10 | 1.080 | 9.263 | 50 | 1.583 | 1.263 |
| 11 | 1.088 | 8.354 | 51 | 1.602 | 1.224 |
| 12 | 1.097 | 7.596 | 52 | 1.621 | 1.186 |
| 13 | 1.106 | 6.955 | 53 | 1.641 | 1.150 |
| 14 | 1.115 | 6.406 | 54 | 1.661 | 1.115 |
| 15 | 1.124 | 5.930 | 55 | 1.681 | 1.081 |
| 16 | 1.134 | 5.513 | 56 | 1.703 | 1.049 |
| 17 | 1.143 | 5.146 | 57 | 1.724 | 1.018 |
| 18 | 1.153 | 4.819 | 58 | 1.746 | 0.987 |
| 19 | 1.163 | 4.526 | 59 | 1.769 | 0.958 |
| 20 | 1.173 | 4.263 | 60 | 1.792 | 0.930 |
| 21 | 1.183 | 4.025 | 61 | 1.816 | 0.903 |
| 22 | 1.193 | 3.809 | 62 | 1.841 | 0.876 |
| 23 | 1.204 | 3.611 | 63 | 1.866 | 0.850 |
| 24 | 1.215 | 3.430 | 64 | 1.892 | 0.826 |
| 25 | 1.226 | 3.263 | 65 | 1.919 | 0.802 |
| 26 | 1.237 | 3.109 | 66 | 1.947 | 0.778 |
| 27 | 1.248 | 2.967 | 67 | 1.975 | 0.756 |
| 28 | 1.260 | 2.835 | 68 | 2.004 | 0.734 |
| 29 | 1.272 | 2.711 | 69 | 2.034 | 0.712 |
| 30 | 1.284 | 2.596 | 70 | 2.065 | 0.692 |
| 31 | 1.296 | 2.489 | 71 | 2.097 | 0.672 |
| 32 | 1.309 | 2.388 | 72 | 2.130 | 0.652 |
| 33 | 1.321 | 2.293 | 73 | 2.164 | 0.633 |
| 34 | 1.334 | 2.204 | 74 | 2.199 | 0.615 |
| 35 | 1.348 | 2.120 | 75 | 2.235 | 0.596 |
| 36 | 1.361 | 2.041 | 76 | 2.273 | 0.579 |
| 37 | 1.375 | 1.966 | 77 | 2.311 | 0.562 |
| 38 | 1.389 | 1.895 | 78 | 2.351 | 0.545 |
| 39 | 1.403 | 1.827 | 79 | 2.393 | 0.529 |
| 40 | 1.418 | 1.763 | 80 | 2.436 | 0.513 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 3.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 23792 | 41 | 1.421 | 411 |
| 2 | 1.015 | 11810 | 42 | 1.435 | 398 |
| 3 | 1.022 | 7815 | 43 | 1.450 | 384 |
| 4 | 1.030 | 5818 | 44 | 1.466 | 372 |
| 5 | 1.037 | 4620 | 45 | 1.481 | 359 |
| 6 | 1.045 | 3821 | 46 | 1.498 | 348 |
| 7 | 1.053 | 3250 | 47 | 1.514 | 337 |
| 8 | 1.061 | 2823 | 48 | 1.531 | 326 |
| 9 | 1.070 | 2490 | 49 | 1.548 | 316 |
| 10 | 1.078 | 2223 | 50 | 1.565 | 306 |
| 11 | 1.086 | 2006 | 51 | 1.583 | 297 |
| 12 | 1.095 | 1824 | 52 | 1.601 | 288 |
| 13 | 1.104 | 1670 | 53 | 1.620 | 279 |
| 14 | 1.112 | 1539 | 54 | 1.639 | 271 |
| 15 | 1.121 | 1424 | 55 | 1.659 | 263 |
| 16 | 1.131 | 1325 | 56 | 1.679 | 255 |
| 17 | 1.140 | 1237 | 57 | 1.700 | 247 |
| 18 | 1.149 | 1158 | 58 | 1.721 | 240 |
| 19 | 1.159 | 1088 | 59 | 1.742 | 233 |
| 20 | 1.169 | 1025 | 60 | 1.765 | 226 |
| 21 | 1.179 | 968 | 61 | 1.787 | 220 |
| 22 | 1.189 | 916 | 62 | 1.811 | 214 |
| 23 | 1.199 | 869 | 63 | 1.835 | 207 |
| 24 | 1.210 | 825 | 64 | 1.860 | 201 |
| 25 | 1.220 | 786 | 65 | 1.885 | 196 |
| 26 | 1.231 | 749 | 66 | 1.911 | 190 |
| 27 | 1.242 | 714 | 67 | 1.938 | 185 |
| 28 | 1.253 | 683 | 68 | 1.965 | 179 |
| 29 | 1.265 | 653 | 69 | 1.993 | 174 |
| 30 | 1.277 | 626 | 70 | 2.022 | 169 |
| 31 | 1.288 | 600 | 71 | 2.052 | 164 |
| 32 | 1.301 | 576 | 72 | 2.083 | 160 |
| 33 | 1.313 | 553 | 73 | 2.115 | 155 |
| 34 | 1.325 | 532 | 74 | 2.148 | 151 |
| 35 | 1.338 | 512 | 75 | 2.182 | 146 |
| 36 | 1.351 | 493 | 76 | 2.217 | 142 |
| 37 | 1.365 | 475 | 77 | 2.253 | 138 |
| 38 | 1.378 | 457 | 78 | 2.290 | 134 |
| 39 | 1.392 | 441 | 79 | 2.329 | 130 |
| 40 | 1.406 | 426 | 80 | 2.368 | 127 |

**Density of solids: 3.8**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.007 | 23789 | 41 | 1.433 | 408 |
| 2 | 1.015 | 11806 | 42 | 1.448 | 394 |
| 3 | 1.023 | 7812 | 43 | 1.464 | 381 |
| 4 | 1.030 | 5815 | 44 | 1.480 | 368 |
| 5 | 1.038 | 4616 | 45 | 1.496 | 356 |
| 6 | 1.046 | 3818 | 46 | 1.513 | 344 |
| 7 | 1.054 | 3247 | 47 | 1.530 | 333 |
| 8 | 1.063 | 2819 | 48 | 1.547 | 323 |
| 9 | 1.071 | 2486 | 49 | 1.565 | 313 |
| 10 | 1.080 | 2220 | 50 | 1.583 | 303 |
| 11 | 1.088 | 2002 | 51 | 1.602 | 293 |
| 12 | 1.097 | 1820 | 52 | 1.621 | 284 |
| 13 | 1.106 | 1667 | 53 | 1.641 | 276 |
| 14 | 1.115 | 1535 | 54 | 1.661 | 267 |
| 15 | 1.124 | 1421 | 55 | 1.681 | 259 |
| 16 | 1.134 | 1321 | 56 | 1.703 | 251 |
| 17 | 1.143 | 1233 | 57 | 1.724 | 244 |
| 18 | 1.153 | 1155 | 58 | 1.746 | 237 |
| 19 | 1.163 | 1085 | 59 | 1.769 | 230 |
| 20 | 1.173 | 1022 | 60 | 1.792 | 223 |
| 21 | 1.183 | 965 | 61 | 1.816 | 216 |
| 22 | 1.193 | 913 | 62 | 1.841 | 210 |
| 23 | 1.204 | 865 | 63 | 1.866 | 204 |
| 24 | 1.215 | 822 | 64 | 1.892 | 198 |
| 25 | 1.226 | 782 | 65 | 1.919 | 192 |
| 26 | 1.237 | 745 | 66 | 1.947 | 186 |
| 27 | 1.248 | 711 | 67 | 1.975 | 181 |
| 28 | 1.260 | 679 | 68 | 2.004 | 176 |
| 29 | 1.272 | 650 | 69 | 2.034 | 171 |
| 30 | 1.284 | 622 | 70 | 2.065 | 166 |
| 31 | 1.296 | 596 | 71 | 2.097 | 161 |
| 32 | 1.309 | 572 | 72 | 2.130 | 156 |
| 33 | 1.321 | 550 | 73 | 2.164 | 152 |
| 34 | 1.334 | 528 | 74 | 2.199 | 147 |
| 35 | 1.348 | 508 | 75 | 2.235 | 143 |
| 36 | 1.361 | 489 | 76 | 2.273 | 139 |
| 37 | 1.375 | 471 | 77 | 2.311 | 135 |
| 38 | 1.389 | 454 | 78 | 2.351 | 131 |
| 39 | 1.403 | 438 | 79 | 2.393 | 127 |
| 40 | 1.418 | 423 | 80 | 2.436 | 123 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 4.2**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 99.238 | 41 | 1.454 | 1.677 |
| 2 | 1.015 | 49.238 | 42 | 1.471 | 1.619 |
| 3 | 1.023 | 32.571 | 43 | 1.487 | 1.564 |
| 4 | 1.031 | 24.238 | 44 | 1.504 | 1.511 |
| 5 | 1.040 | 19.238 | 45 | 1.522 | 1.460 |
| 6 | 1.048 | 15.905 | 46 | 1.540 | 1.412 |
| 7 | 1.056 | 13.524 | 47 | 1.558 | 1.366 |
| 8 | 1.065 | 11.738 | 48 | 1.577 | 1.321 |
| 9 | 1.074 | 10.349 | 49 | 1.596 | 1.279 |
| 10 | 1.082 | 9.238 | 50 | 1.615 | 1.238 |
| 11 | 1.091 | 8.329 | 51 | 1.636 | 1.199 |
| 12 | 1.101 | 7.571 | 52 | 1.656 | 1.161 |
| 13 | 1.110 | 6.930 | 53 | 1.677 | 1.125 |
| 14 | 1.119 | 6.381 | 54 | 1.699 | 1.090 |
| 15 | 1.129 | 5.905 | 55 | 1.721 | 1.056 |
| 16 | 1.139 | 5.488 | 56 | 1.744 | 1.024 |
| 17 | 1.149 | 5.120 | 57 | 1.768 | 0.992 |
| 18 | 1.159 | 4.794 | 58 | 1.792 | 0.962 |
| 19 | 1.169 | 4.501 | 59 | 1.817 | 0.933 |
| 20 | 1.180 | 4.238 | 60 | 1.842 | 0.905 |
| 21 | 1.190 | 4.000 | 61 | 1.868 | 0.877 |
| 22 | 1.201 | 3.784 | 62 | 1.895 | 0.851 |
| 23 | 1.212 | 3.586 | 63 | 1.923 | 0.825 |
| 24 | 1.224 | 3.405 | 64 | 1.952 | 0.801 |
| 25 | 1.235 | 3.238 | 65 | 1.981 | 0.777 |
| 26 | 1.247 | 3.084 | 66 | 2.011 | 0.753 |
| 27 | 1.259 | 2.942 | 67 | 2.043 | 0.731 |
| 28 | 1.271 | 2.810 | 68 | 2.075 | 0.709 |
| 29 | 1.284 | 2.686 | 69 | 2.108 | 0.687 |
| 30 | 1.296 | 2.571 | 70 | 2.143 | 0.667 |
| 31 | 1.309 | 2.464 | 71 | 2.178 | 0.647 |
| 32 | 1.322 | 2.363 | 72 | 2.215 | 0.627 |
| 33 | 1.336 | 2.268 | 73 | 2.253 | 0.608 |
| 34 | 1.350 | 2.179 | 74 | 2.293 | 0.589 |
| 35 | 1.364 | 2.095 | 75 | 2.333 | 0.571 |
| 36 | 1.378 | 2.016 | 76 | 2.376 | 0.554 |
| 37 | 1.393 | 1.941 | 77 | 2.419 | 0.537 |
| 38 | 1.408 | 1.870 | 78 | 2.465 | 0.520 |
| 39 | 1.423 | 1.802 | 79 | 2.512 | 0.504 |
| 40 | 1.438 | 1.738 | 80 | 2.561 | 0.488 |

**Density of solids: 4.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 99.217 | 41 | 1.472 | 1.656 |
| 2 | 1.016 | 49.217 | 42 | 1.490 | 1.598 |
| 3 | 1.024 | 32.551 | 43 | 1.507 | 1.543 |
| 4 | 1.032 | 24.217 | 44 | 1.525 | 1.490 |
| 5 | 1.041 | 19.217 | 45 | 1.544 | 1.440 |
| 6 | 1.049 | 15.884 | 46 | 1.563 | 1.391 |
| 7 | 1.058 | 13.503 | 47 | 1.582 | 1.345 |
| 8 | 1.067 | 11.717 | 48 | 1.602 | 1.301 |
| 9 | 1.076 | 10.329 | 49 | 1.622 | 1.258 |
| 10 | 1.085 | 9.217 | 50 | 1.643 | 1.217 |
| 11 | 1.094 | 8.308 | 51 | 1.664 | 1.178 |
| 12 | 1.104 | 7.551 | 52 | 1.686 | 1.140 |
| 13 | 1.113 | 6.910 | 53 | 1.709 | 1.104 |
| 14 | 1.123 | 6.360 | 54 | 1.732 | 1.069 |
| 15 | 1.133 | 5.884 | 55 | 1.756 | 1.036 |
| 16 | 1.143 | 5.467 | 56 | 1.780 | 1.003 |
| 17 | 1.153 | 5.100 | 57 | 1.805 | 0.972 |
| 18 | 1.164 | 4.773 | 58 | 1.831 | 0.942 |
| 19 | 1.175 | 4.481 | 59 | 1.858 | 0.912 |
| 20 | 1.186 | 4.217 | 60 | 1.885 | 0.884 |
| 21 | 1.197 | 3.979 | 61 | 1.913 | 0.857 |
| 22 | 1.208 | 3.763 | 62 | 1.943 | 0.830 |
| 23 | 1.220 | 3.565 | 63 | 1.973 | 0.805 |
| 24 | 1.231 | 3.384 | 64 | 2.003 | 0.780 |
| 25 | 1.243 | 3.217 | 65 | 2.035 | 0.756 |
| 26 | 1.255 | 3.064 | 66 | 2.068 | 0.733 |
| 27 | 1.268 | 2.921 | 67 | 2.102 | 0.710 |
| 28 | 1.281 | 2.789 | 68 | 2.138 | 0.688 |
| 29 | 1.294 | 2.666 | 69 | 2.174 | 0.667 |
| 30 | 1.307 | 2.551 | 70 | 2.212 | 0.646 |
| 31 | 1.320 | 2.443 | 71 | 2.250 | 0.626 |
| 32 | 1.334 | 2.342 | 72 | 2.291 | 0.606 |
| 33 | 1.348 | 2.248 | 73 | 2.333 | 0.587 |
| 34 | 1.363 | 2.159 | 74 | 2.376 | 0.569 |
| 35 | 1.377 | 2.075 | 75 | 2.421 | 0.551 |
| 36 | 1.392 | 1.995 | 76 | 2.468 | 0.533 |
| 37 | 1.408 | 1.920 | 77 | 2.516 | 0.516 |
| 38 | 1.423 | 1.849 | 78 | 2.567 | 0.499 |
| 39 | 1.439 | 1.781 | 79 | 2.620 | 0.483 |
| 40 | 1.456 | 1.717 | 80 | 2.674 | 0.467 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 4.2**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 23783 | 41 | 1.454 | 402 |
| 2 | 1.015 | 11800 | 42 | 1.471 | 388 |
| 3 | 1.023 | 7806 | 43 | 1.487 | 375 |
| 4 | 1.031 | 5809 | 44 | 1.504 | 362 |
| 5 | 1.040 | 4610 | 45 | 1.522 | 350 |
| 6 | 1.048 | 3812 | 46 | 1.540 | 338 |
| 7 | 1.056 | 3241 | 47 | 1.558 | 327 |
| 8 | 1.065 | 2813 | 48 | 1.577 | 317 |
| 9 | 1.074 | 2480 | 49 | 1.596 | 307 |
| 10 | 1.082 | 2214 | 50 | 1.615 | 297 |
| 11 | 1.091 | 1996 | 51 | 1.636 | 287 |
| 12 | 1.101 | 1814 | 52 | 1.656 | 278 |
| 13 | 1.110 | 1661 | 53 | 1.677 | 270 |
| 14 | 1.119 | 1529 | 54 | 1.699 | 261 |
| 15 | 1.129 | 1415 | 55 | 1.721 | 253 |
| 16 | 1.139 | 1315 | 56 | 1.744 | 245 |
| 17 | 1.149 | 1227 | 57 | 1.768 | 238 |
| 18 | 1.159 | 1149 | 58 | 1.792 | 231 |
| 19 | 1.169 | 1079 | 59 | 1.817 | 224 |
| 20 | 1.180 | 1016 | 60 | 1.842 | 217 |
| 21 | 1.190 | 959 | 61 | 1.868 | 210 |
| 22 | 1.201 | 907 | 62 | 1.895 | 204 |
| 23 | 1.212 | 859 | 63 | 1.923 | 198 |
| 24 | 1.224 | 816 | 64 | 1.952 | 192 |
| 25 | 1.235 | 776 | 65 | 1.981 | 186 |
| 26 | 1.247 | 739 | 66 | 2.011 | 180 |
| 27 | 1.259 | 705 | 67 | 2.043 | 175 |
| 28 | 1.271 | 673 | 68 | 2.075 | 170 |
| 29 | 1.284 | 644 | 69 | 2.108 | 165 |
| 30 | 1.296 | 616 | 70 | 2.143 | 160 |
| 31 | 1.309 | 591 | 71 | 2.178 | 155 |
| 32 | 1.322 | 566 | 72 | 2.215 | 150 |
| 33 | 1.336 | 544 | 73 | 2.253 | 146 |
| 34 | 1.350 | 522 | 74 | 2.293 | 141 |
| 35 | 1.364 | 502 | 75 | 2.333 | 137 |
| 36 | 1.378 | 483 | 76 | 2.376 | 133 |
| 37 | 1.393 | 465 | 77 | 2.419 | 129 |
| 38 | 1.408 | 448 | 78 | 2.465 | 125 |
| 39 | 1.423 | 432 | 79 | 2.512 | 121 |
| 40 | 1.438 | 417 | 80 | 2.561 | 117 |

**Density of solids: 4.6**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 23778 | 41 | 1.472 | 397 |
| 2 | 1.016 | 11795 | 42 | 1.490 | 383 |
| 3 | 1.024 | 7801 | 43 | 1.507 | 370 |
| 4 | 1.032 | 5804 | 44 | 1.525 | 357 |
| 5 | 1.041 | 4605 | 45 | 1.544 | 345 |
| 6 | 1.049 | 3807 | 46 | 1.563 | 333 |
| 7 | 1.058 | 3236 | 47 | 1.582 | 322 |
| 8 | 1.067 | 2808 | 48 | 1.602 | 312 |
| 9 | 1.076 | 2475 | 49 | 1.622 | 301 |
| 10 | 1.085 | 2209 | 50 | 1.643 | 292 |
| 11 | 1.094 | 1991 | 51 | 1.664 | 282 |
| 12 | 1.104 | 1810 | 52 | 1.686 | 273 |
| 13 | 1.113 | 1656 | 53 | 1.709 | 265 |
| 14 | 1.123 | 1524 | 54 | 1.732 | 256 |
| 15 | 1.133 | 1410 | 55 | 1.756 | 248 |
| 16 | 1.143 | 1310 | 56 | 1.780 | 240 |
| 17 | 1.153 | 1222 | 57 | 1.805 | 233 |
| 18 | 1.164 | 1144 | 58 | 1.831 | 226 |
| 19 | 1.175 | 1074 | 59 | 1.858 | 219 |
| 20 | 1.186 | 1011 | 60 | 1.885 | 212 |
| 21 | 1.197 | 954 | 61 | 1.913 | 205 |
| 22 | 1.208 | 902 | 62 | 1.943 | 199 |
| 23 | 1.220 | 854 | 63 | 1.973 | 193 |
| 24 | 1.231 | 811 | 64 | 2.003 | 187 |
| 25 | 1.243 | 771 | 65 | 2.035 | 181 |
| 26 | 1.255 | 734 | 66 | 2.068 | 176 |
| 27 | 1.268 | 700 | 67 | 2.102 | 170 |
| 28 | 1.281 | 668 | 68 | 2.138 | 165 |
| 29 | 1.294 | 639 | 69 | 2.174 | 160 |
| 30 | 1.307 | 611 | 70 | 2.212 | 155 |
| 31 | 1.320 | 585 | 71 | 2.250 | 150 |
| 32 | 1.334 | 561 | 72 | 2.291 | 145 |
| 33 | 1.348 | 539 | 73 | 2.333 | 141 |
| 34 | 1.363 | 517 | 74 | 2.376 | 136 |
| 35 | 1.377 | 497 | 75 | 2.421 | 132 |
| 36 | 1.392 | 478 | 76 | 2.468 | 128 |
| 37 | 1.408 | 460 | 77 | 2.516 | 124 |
| 38 | 1.423 | 443 | 78 | 2.567 | 120 |
| 39 | 1.439 | 427 | 79 | 2.620 | 116 |
| 40 | 1.456 | 411 | 80 | 2.674 | 112 |

## *Water and solids – Pulp density data (metric)*

A = Solids by weight [%]
B = Pulp density [ton/$m^3$]
C = Pulp volume [$m^3$/ton solids]

**Density of solids: 5.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 99.200 | 41 | 1.488 | 1.639 |
| 2 | 1.016 | 49.200 | 42 | 1.506 | 1.581 |
| 3 | 1.025 | 32.533 | 43 | 1.524 | 1.526 |
| 4 | 1.033 | 24.200 | 44 | 1.543 | 1.473 |
| 5 | 1.042 | 19.200 | 45 | 1.563 | 1.422 |
| 6 | 1.050 | 15.867 | 46 | 1.582 | 1.374 |
| 7 | 1.059 | 13.486 | 47 | 1.603 | 1.328 |
| 8 | 1.068 | 11.700 | 48 | 1.623 | 1.283 |
| 9 | 1.078 | 10.311 | 49 | 1.645 | 1.241 |
| 10 | 1.087 | 9.200 | 50 | 1.667 | 1.200 |
| 11 | 1.096 | 8.291 | 51 | 1.689 | 1.161 |
| 12 | 1.106 | 7.533 | 52 | 1.712 | 1.123 |
| 13 | 1.116 | 6.892 | 53 | 1.736 | 1.087 |
| 14 | 1.126 | 6.343 | 54 | 1.761 | 1.052 |
| 15 | 1.136 | 5.867 | 55 | 1.786 | 1.018 |
| 16 | 1.147 | 5.450 | 56 | 1.812 | 0.986 |
| 17 | 1.157 | 5.082 | 57 | 1.838 | 0.954 |
| 18 | 1.168 | 4.756 | 58 | 1.866 | 0.924 |
| 19 | 1.179 | 4.463 | 59 | 1.894 | 0.895 |
| 20 | 1.190 | 4.200 | 60 | 1.923 | 0.867 |
| 21 | 1.202 | 3.962 | 61 | 1.953 | 0.839 |
| 22 | 1.214 | 3.745 | 62 | 1.984 | 0.813 |
| 23 | 1.225 | 3.548 | 63 | 2.016 | 0.787 |
| 24 | 1.238 | 3.367 | 64 | 2.049 | 0.763 |
| 25 | 1.250 | 3.200 | 65 | 2.083 | 0.738 |
| 26 | 1.263 | 3.046 | 66 | 2.119 | 0.715 |
| 27 | 1.276 | 2.904 | 67 | 2.155 | 0.693 |
| 28 | 1.289 | 2.771 | 68 | 2.193 | 0.671 |
| 29 | 1.302 | 2.648 | 69 | 2.232 | 0.649 |
| 30 | 1.316 | 2.533 | 70 | 2.273 | 0.629 |
| 31 | 1.330 | 2.426 | 71 | 2.315 | 0.608 |
| 32 | 1.344 | 2.325 | 72 | 2.358 | 0.589 |
| 33 | 1.359 | 2.230 | 73 | 2.404 | 0.570 |
| 34 | 1.374 | 2.141 | 74 | 2.451 | 0.551 |
| 35 | 1.389 | 2.057 | 75 | 2.500 | 0.533 |
| 36 | 1.404 | 1.978 | 76 | 2.551 | 0.516 |
| 37 | 1.420 | 1.903 | 77 | 2.604 | 0.499 |
| 38 | 1.437 | 1.832 | 78 | 2.660 | 0.482 |
| 39 | 1.453 | 1.764 | 79 | 2.717 | 0.466 |
| 40 | 1.471 | 1.700 | 80 | 2.778 | 0.450 |

## *Water and solids – Pulp density data (US)*

A = Solids by weight [%]
B = Pulp density
C = Pulp volume [USG/ston solids]

**Density of solids: 5.0**

| A | B | C | A | B | C |
|---|---|---|---|---|---|
| 1 | 1.008 | 23774 | 41 | 1.488 | 393 |
| 2 | 1.016 | 11791 | 42 | 1.506 | 379 |
| 3 | 1.025 | 7797 | 43 | 1.524 | 366 |
| 4 | 1.033 | 5800 | 44 | 1.543 | 353 |
| 5 | 1.042 | 4601 | 45 | 1.563 | 341 |
| 6 | 1.050 | 3803 | 46 | 1.582 | 329 |
| 7 | 1.059 | 3232 | 47 | 1.603 | 318 |
| 8 | 1.068 | 2804 | 48 | 1.623 | 307 |
| 9 | 1.078 | 2471 | 49 | 1.645 | 297 |
| 10 | 1.087 | 2205 | 50 | 1.667 | 288 |
| 11 | 1.096 | 1987 | 51 | 1.689 | 278 |
| 12 | 1.106 | 1805 | 52 | 1.712 | 269 |
| 13 | 1.116 | 1652 | 53 | 1.736 | 261 |
| 14 | 1.126 | 1520 | 54 | 1.761 | 252 |
| 15 | 1.136 | 1406 | 55 | 1.786 | 244 |
| 16 | 1.147 | 1306 | 56 | 1.812 | 236 |
| 17 | 1.157 | 1218 | 57 | 1.838 | 229 |
| 18 | 1.168 | 1140 | 58 | 1.866 | 221 |
| 19 | 1.179 | 1070 | 59 | 1.894 | 214 |
| 20 | 1.190 | 1007 | 60 | 1.923 | 208 |
| 21 | 1.202 | 950 | 61 | 1.953 | 201 |
| 22 | 1.214 | 897 | 62 | 1.984 | 195 |
| 23 | 1.225 | 850 | 63 | 2.016 | 189 |
| 24 | 1.238 | 807 | 64 | 2.049 | 183 |
| 25 | 1.250 | 767 | 65 | 2.083 | 177 |
| 26 | 1.263 | 730 | 66 | 2.119 | 171 |
| 27 | 1.276 | 696 | 67 | 2.155 | 166 |
| 28 | 1.289 | 664 | 68 | 2.193 | 161 |
| 29 | 1.302 | 635 | 69 | 2.232 | 156 |
| 30 | 1.316 | 607 | 70 | 2.273 | 151 |
| 31 | 1.330 | 581 | 71 | 2.315 | 146 |
| 32 | 1.344 | 557 | 72 | 2.358 | 141 |
| 33 | 1.359 | 534 | 73 | 2.404 | 137 |
| 34 | 1.374 | 513 | 74 | 2.451 | 132 |
| 35 | 1.389 | 493 | 75 | 2.500 | 128 |
| 36 | 1.404 | 474 | 76 | 2.551 | 124 |
| 37 | 1.420 | 456 | 77 | 2.604 | 120 |
| 38 | 1.437 | 439 | 78 | 2.660 | 116 |
| 39 | 1.453 | 423 | 79 | 2.717 | 112 |
| 40 | 1.471 | 407 | 80 | 2.778 | 108 |

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